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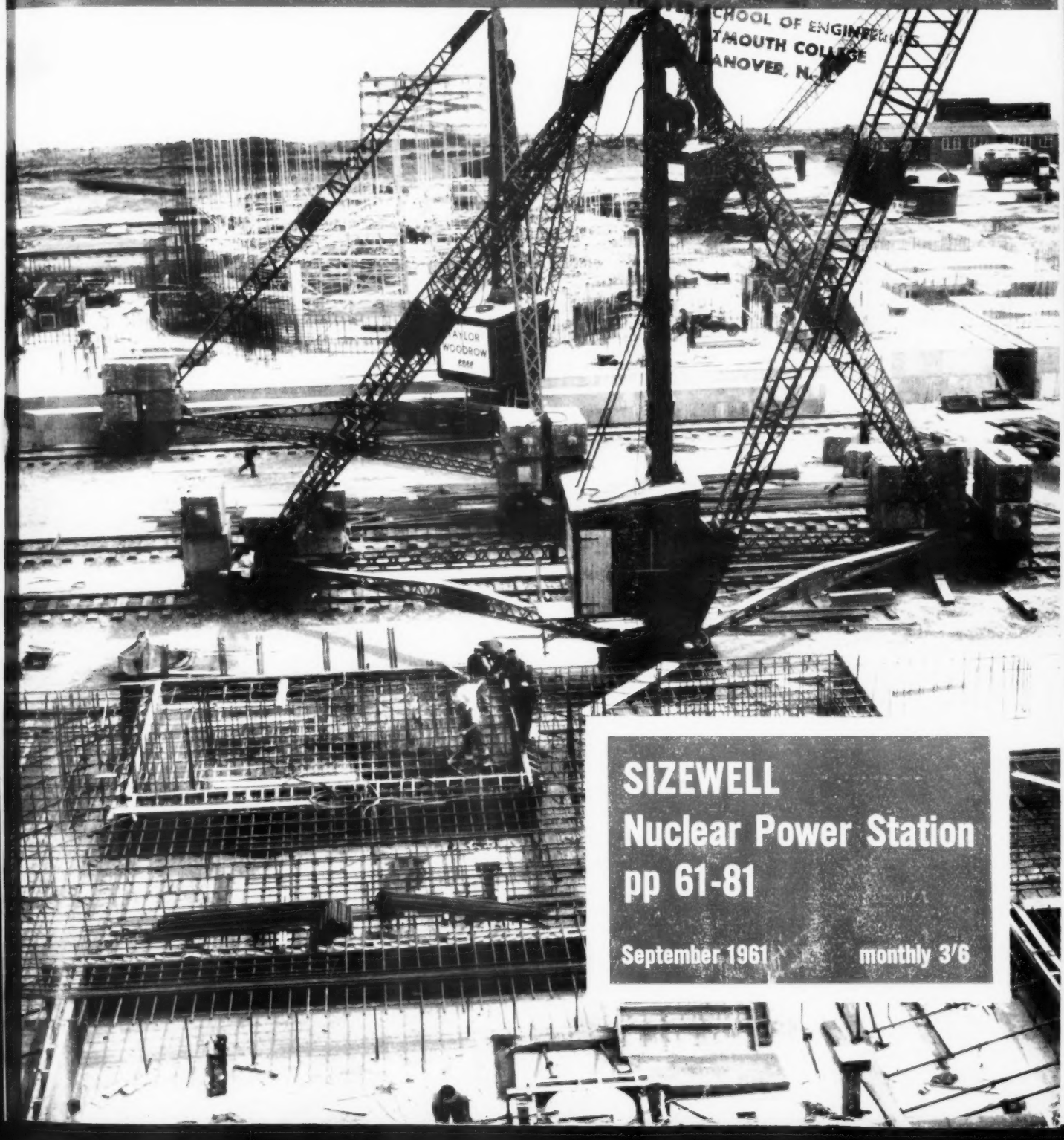
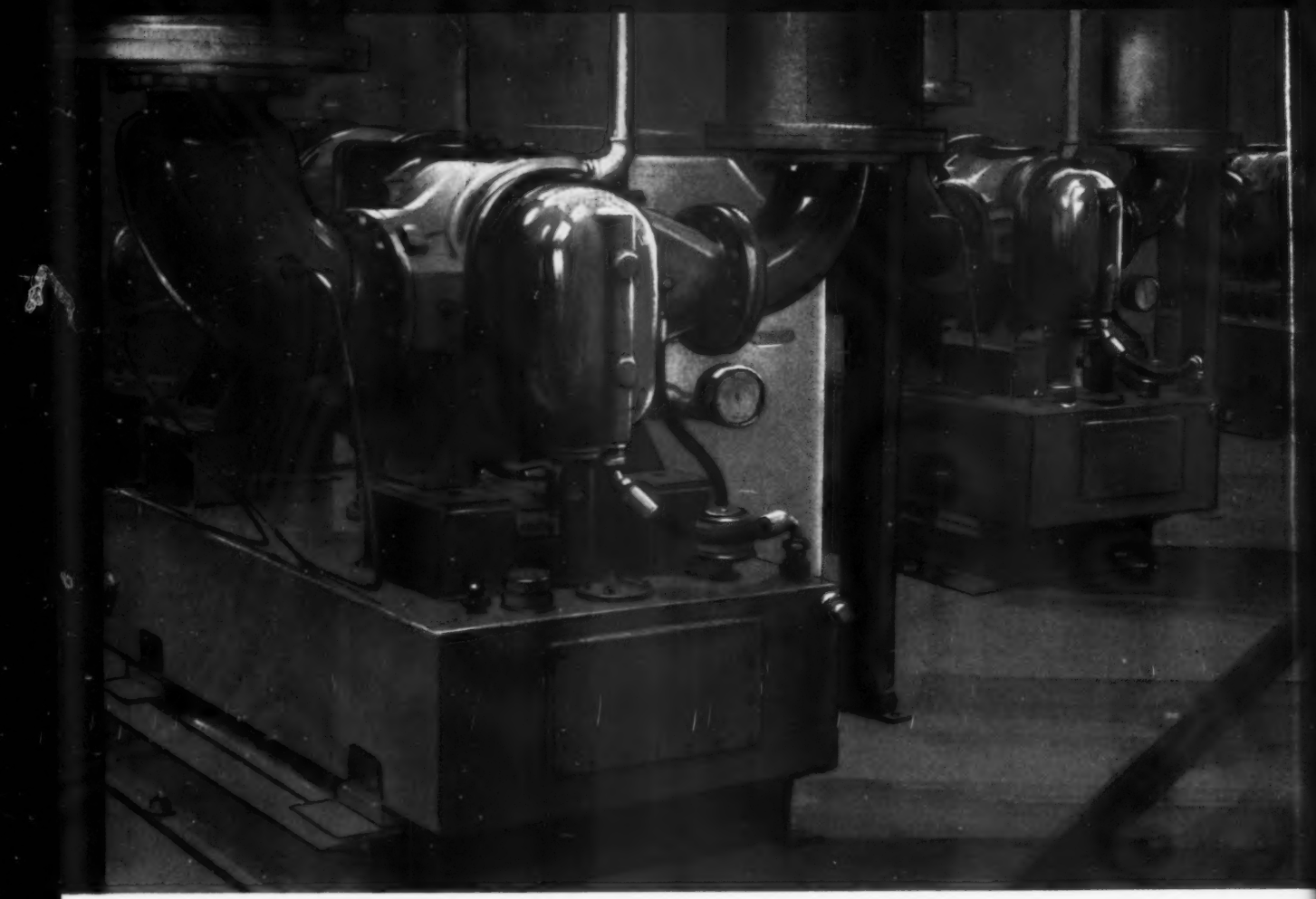


SIZEWELL
Nuclear Power Station
pp 61-81

September 1961 monthly 3/6



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VOL 6 NO 65 SEPTEMBER 1961

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COVER PICTURE

Looking seawards over the raft foundation of Sizewell's two reactors.

SPECIAL FEATURES

THE SIZEWELL NUCLEAR POWER STATION

This 580 MWe power station is the latest of the descendants of Calder Hall. Designers from the English Electric, Babcock & Wilcox, Taylor Woodrow Atomic Power Group contribute to the first detailed and authoritative description

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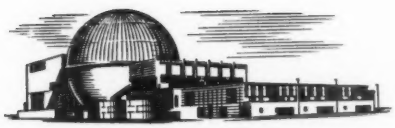

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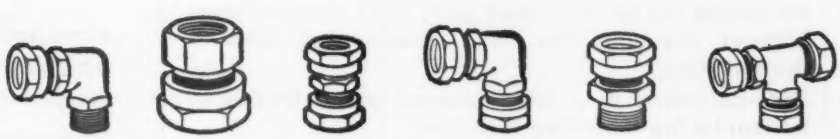

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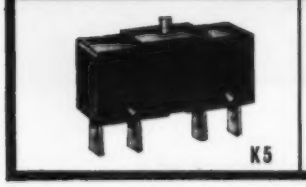

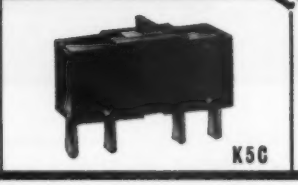

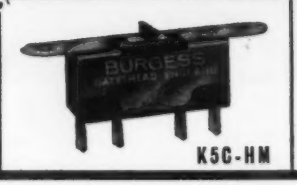

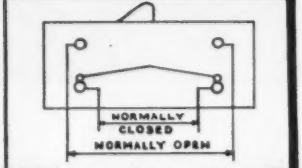

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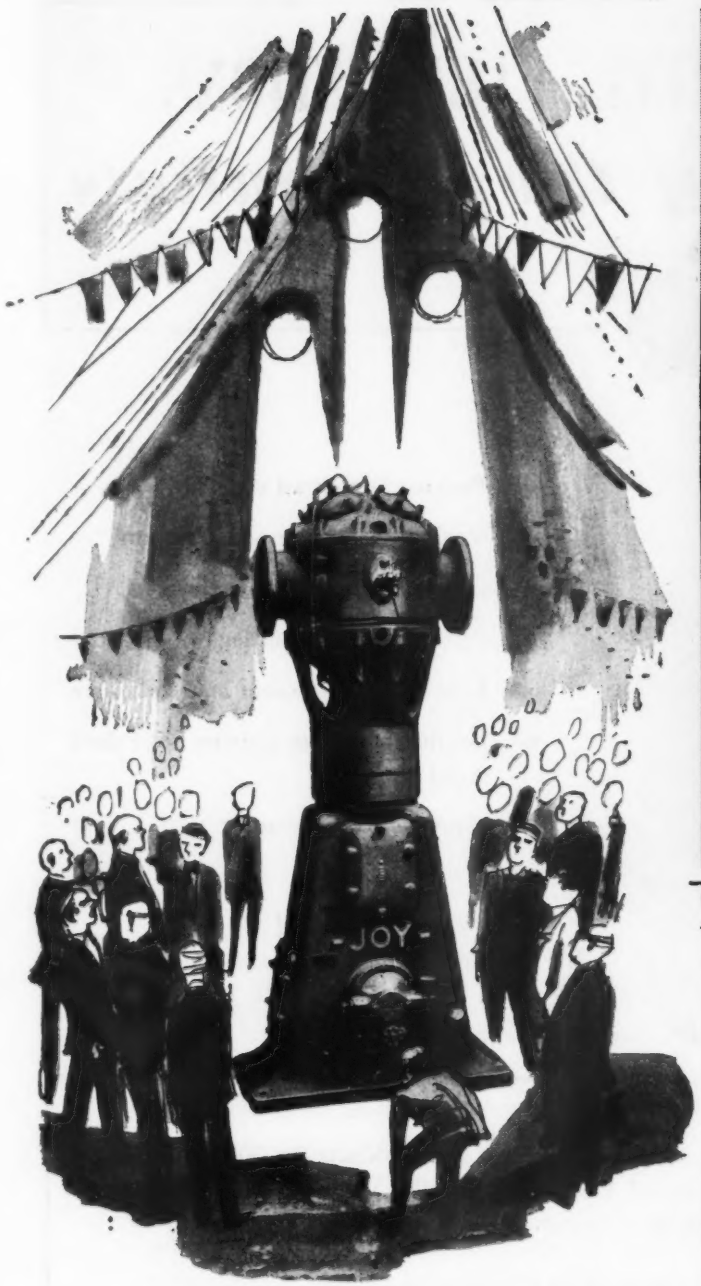

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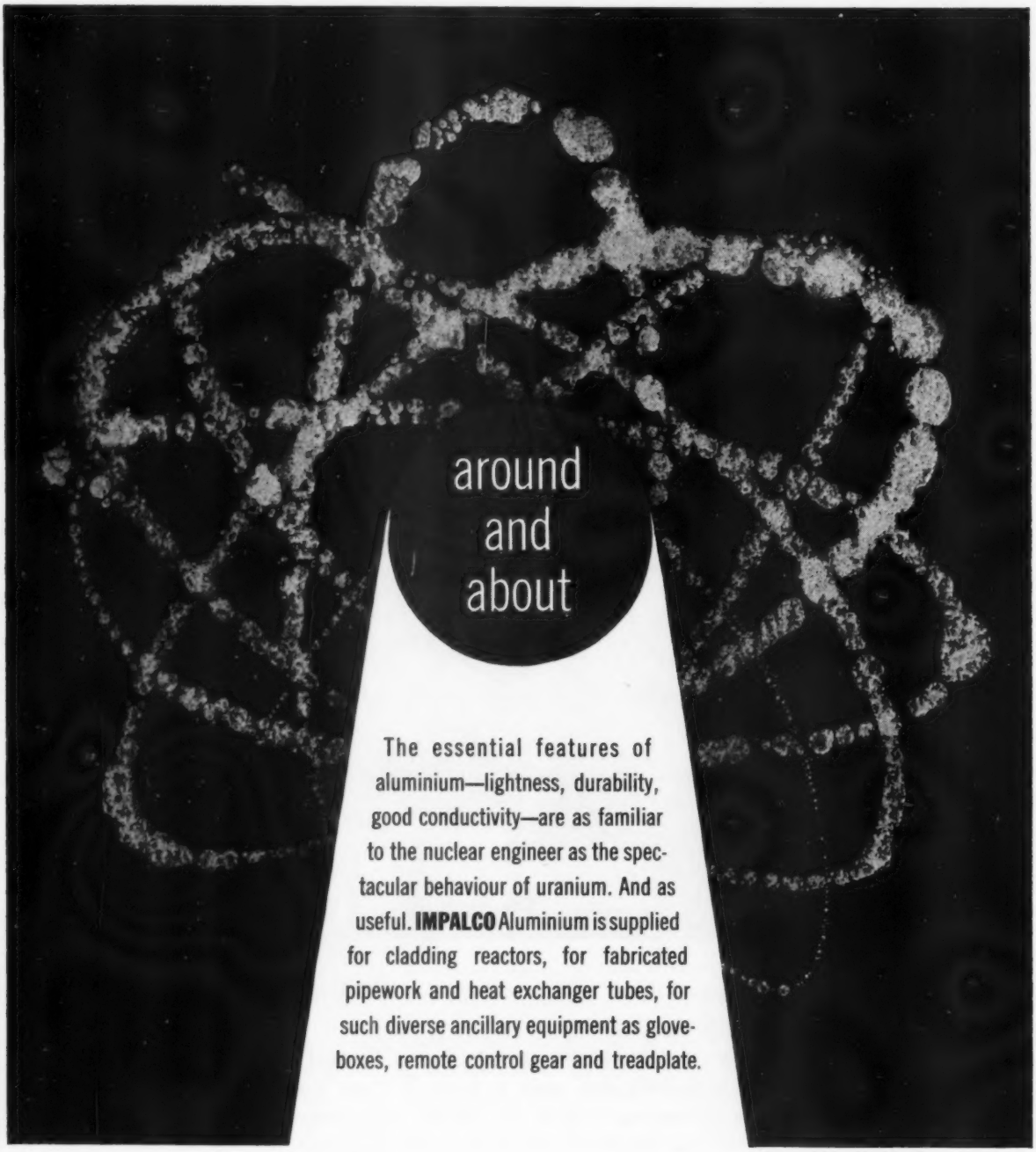

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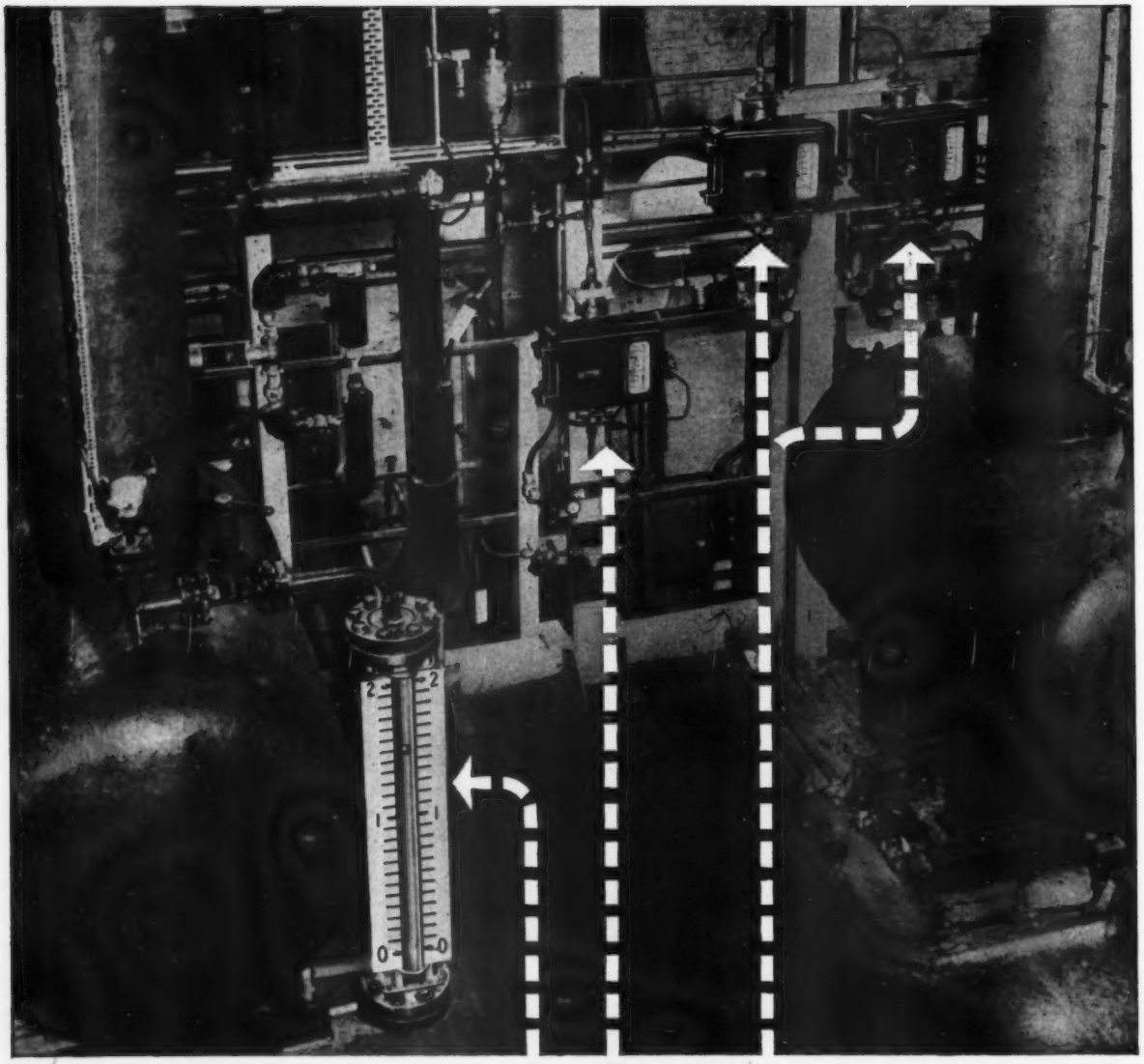

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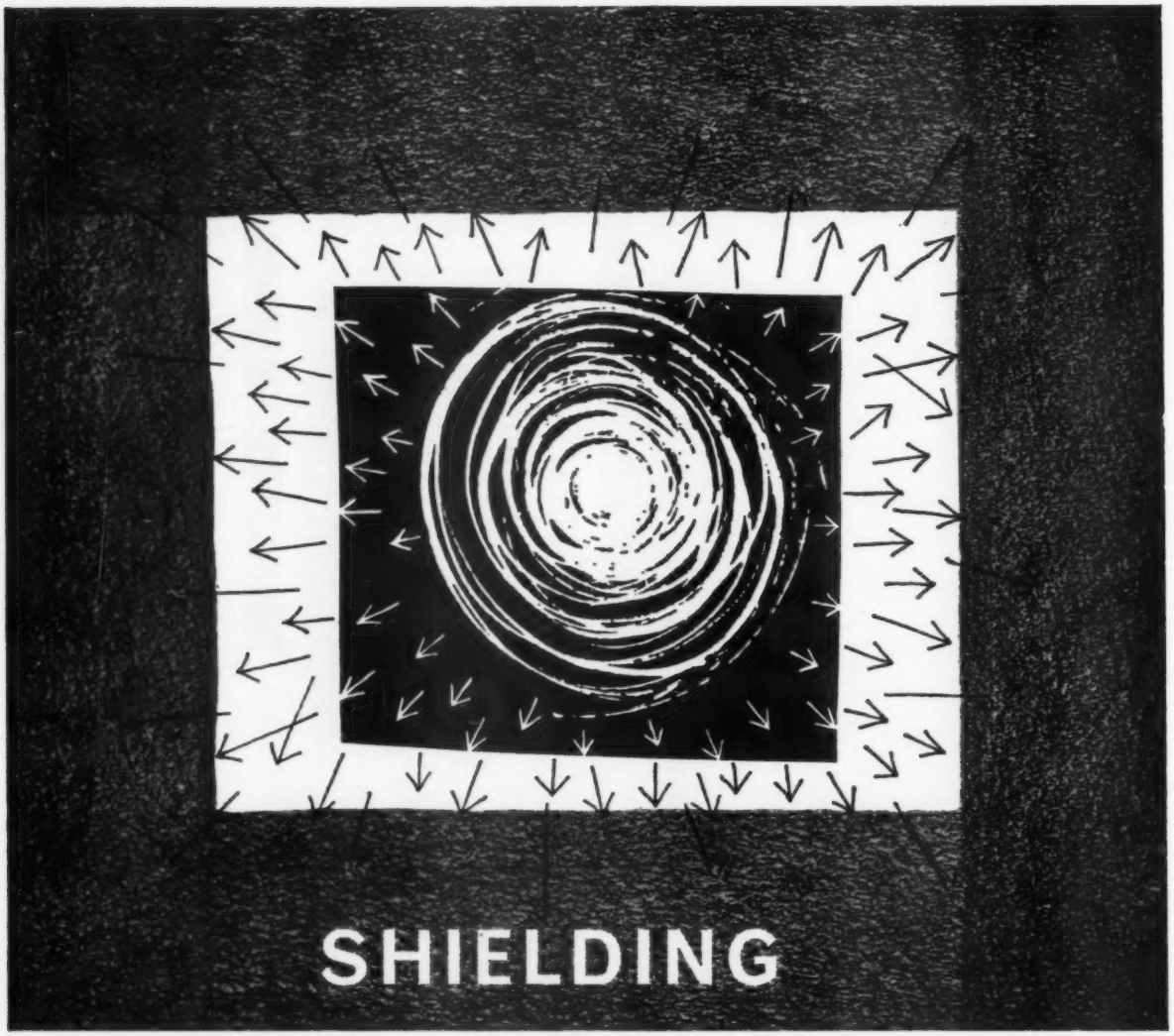

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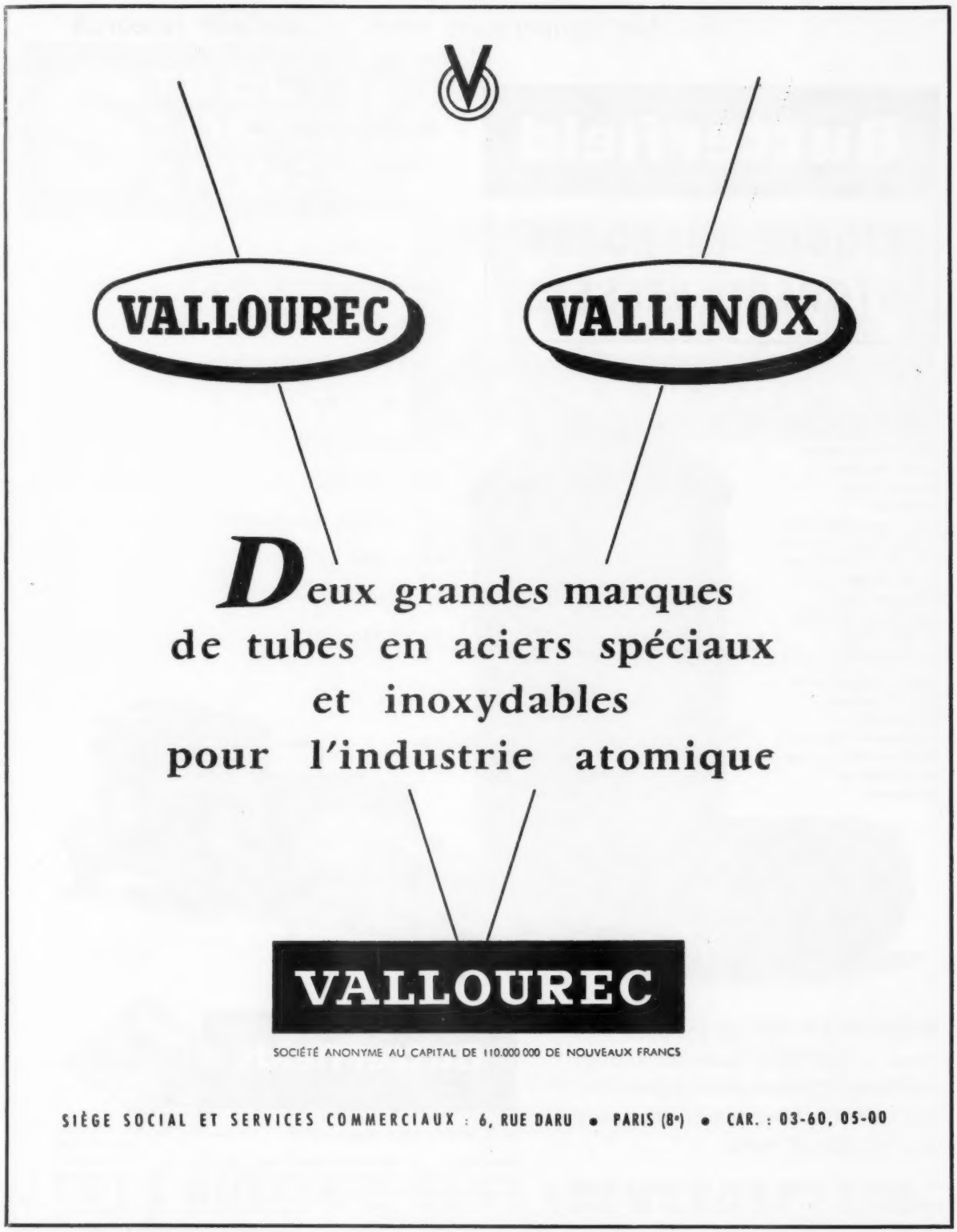
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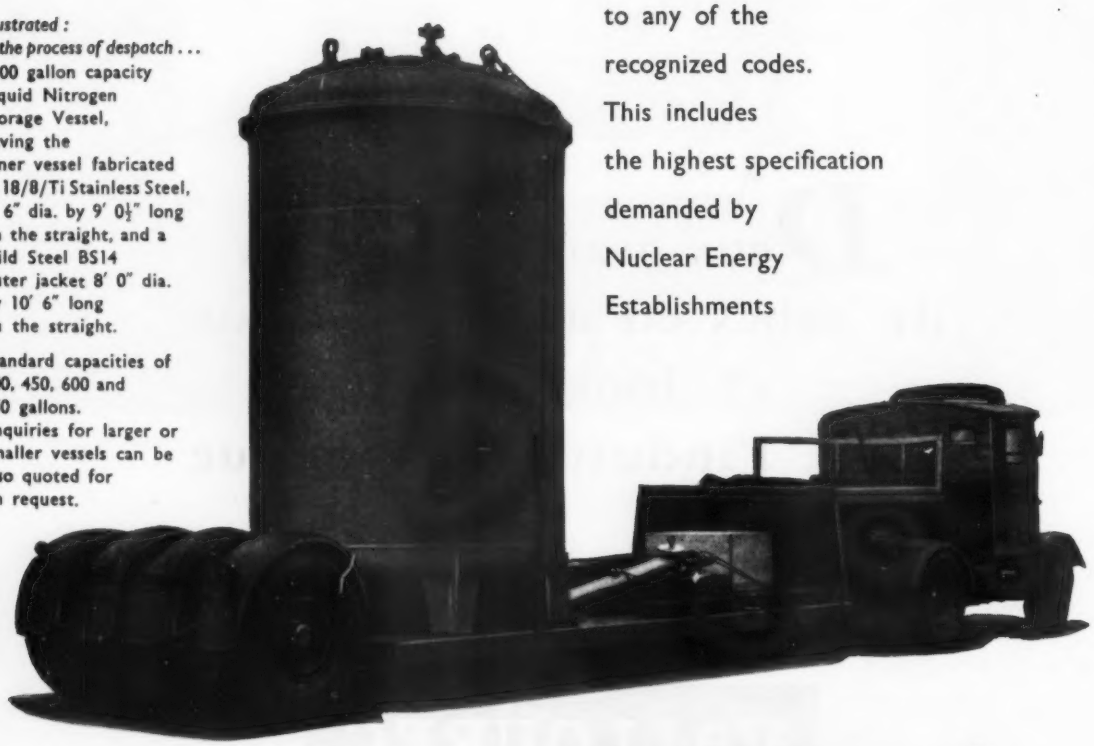

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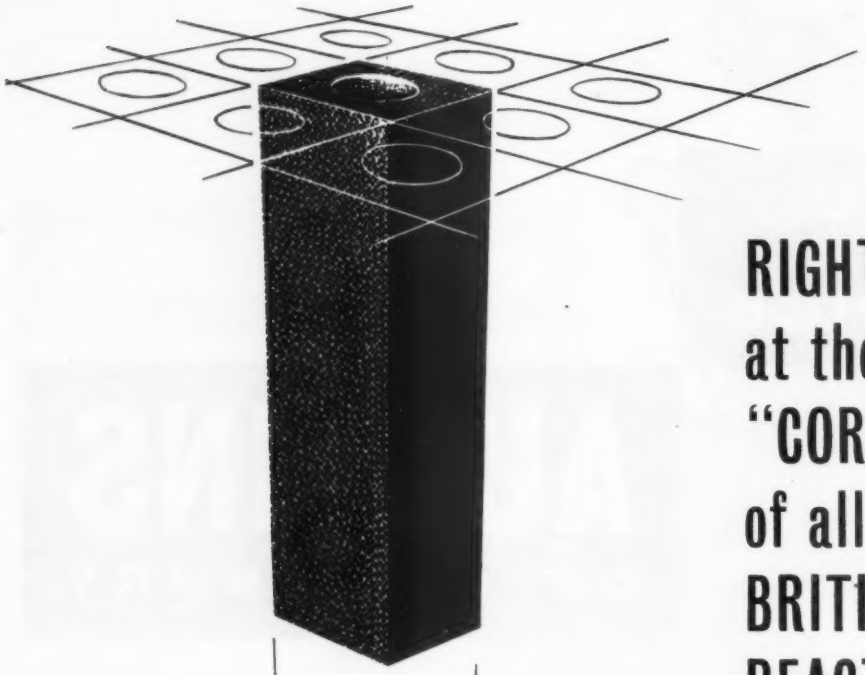

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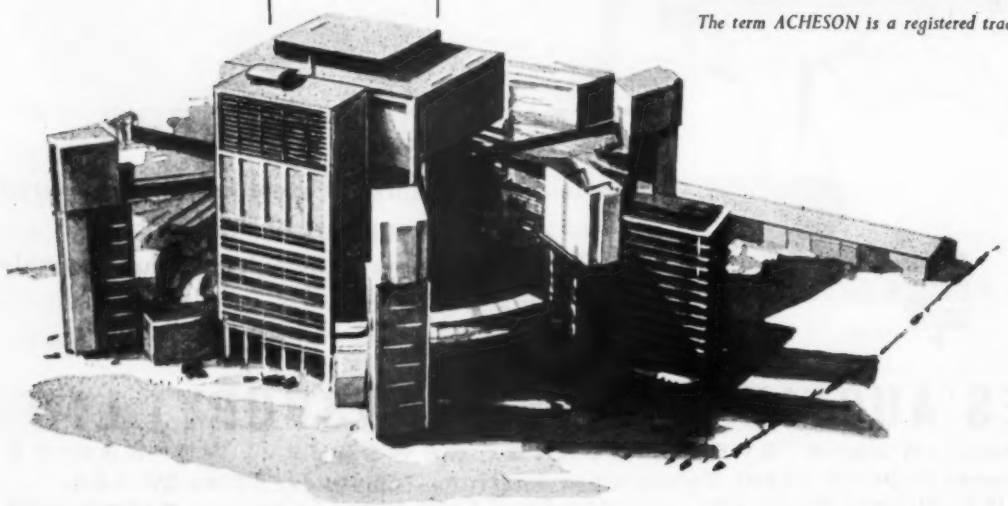

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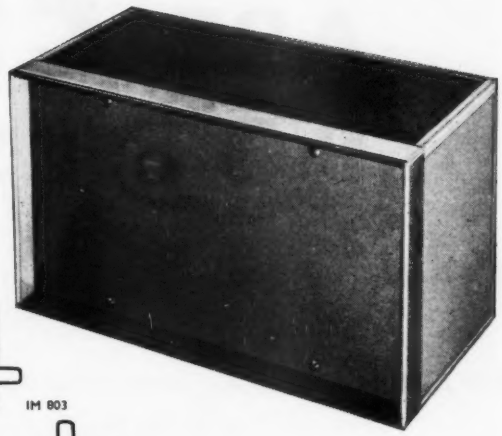

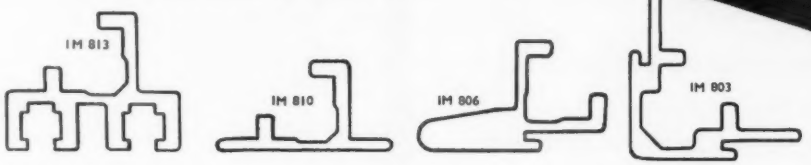

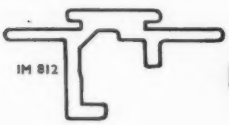

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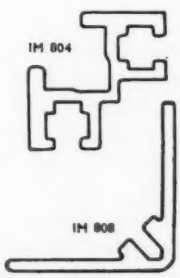

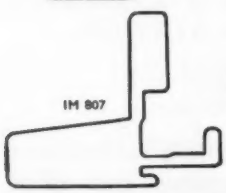

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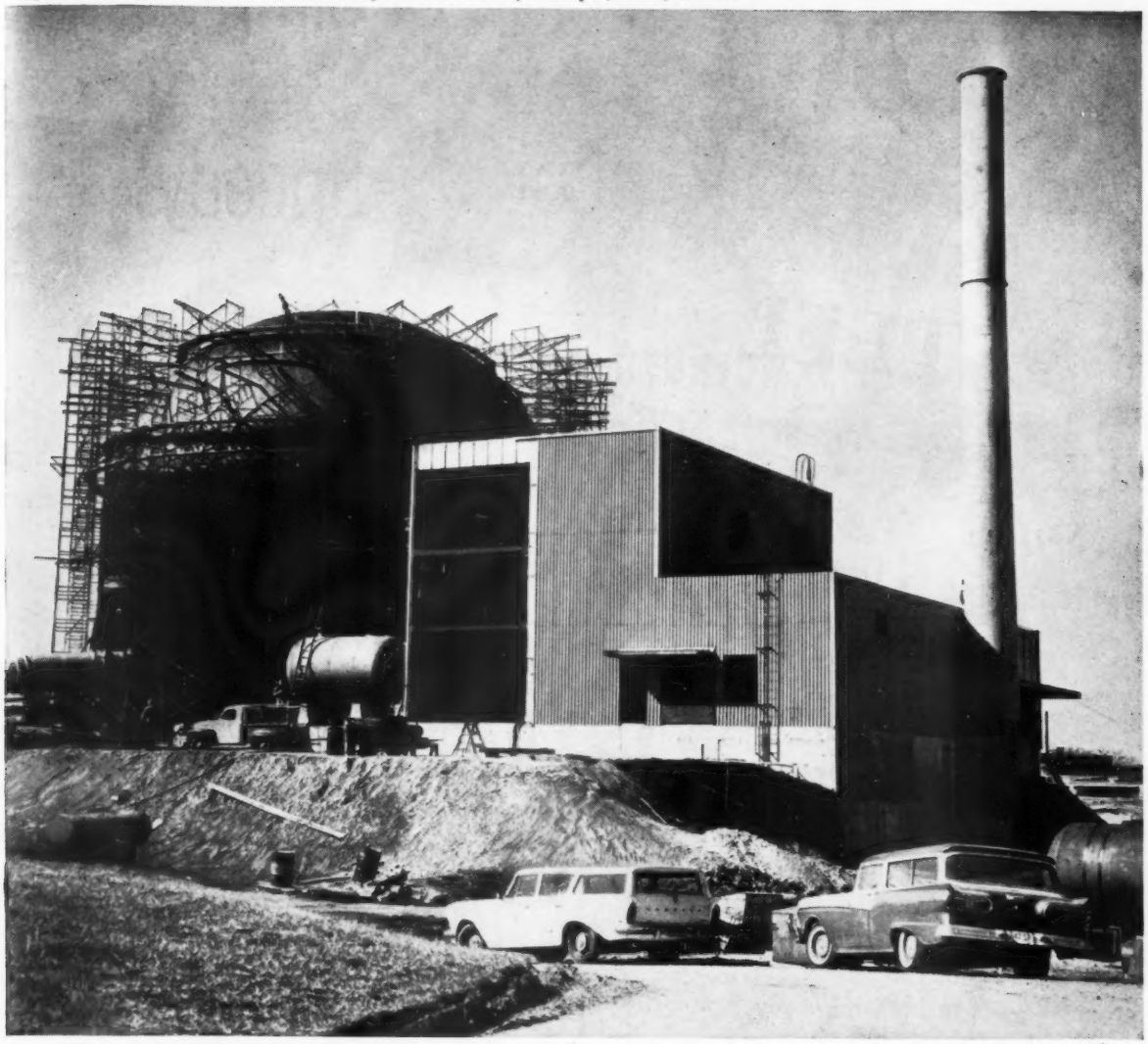

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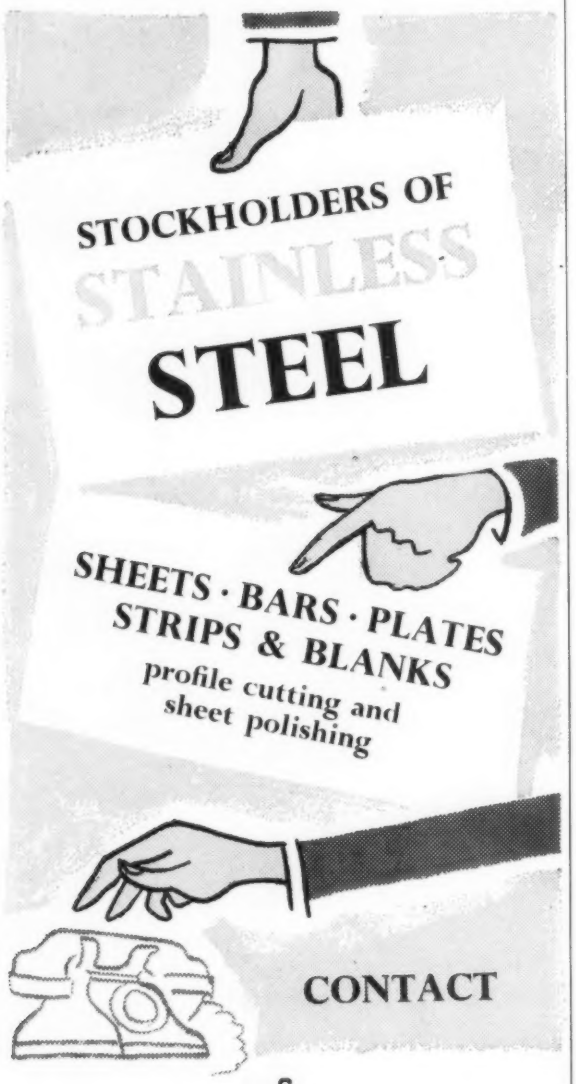

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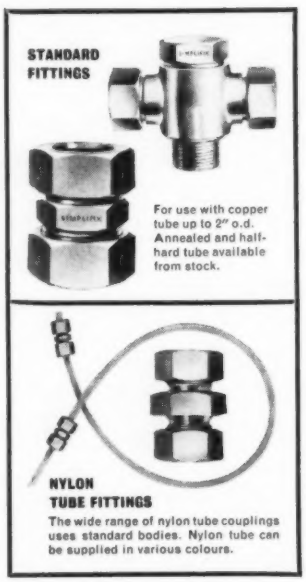
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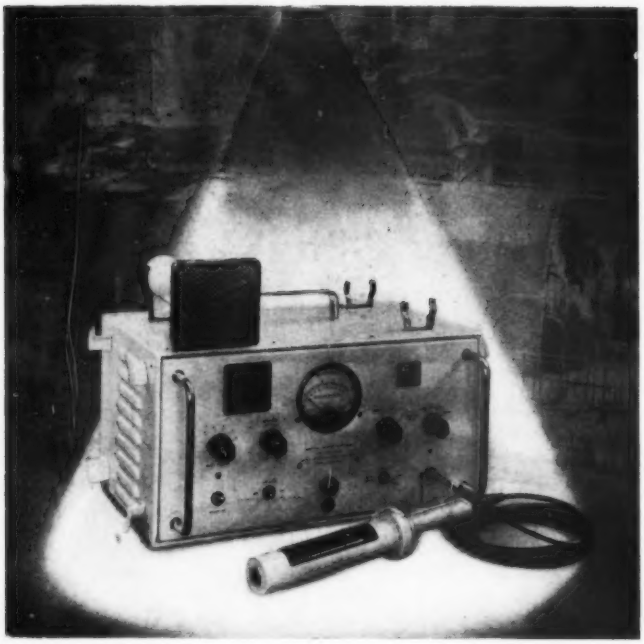

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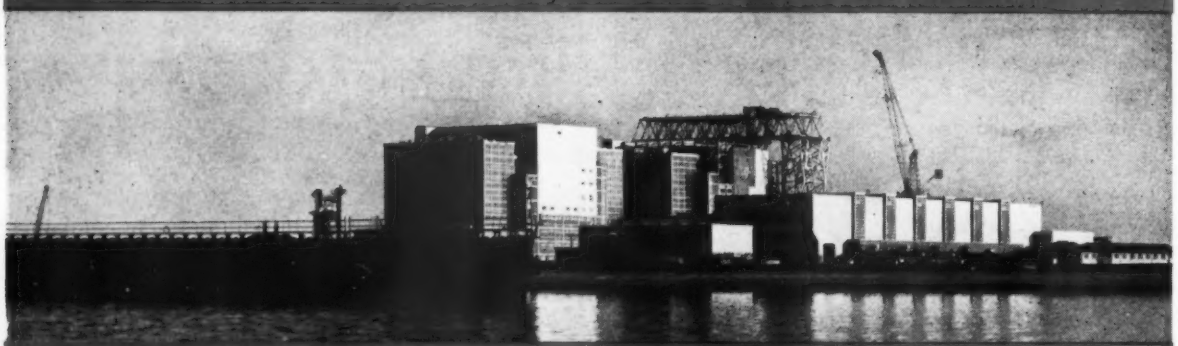

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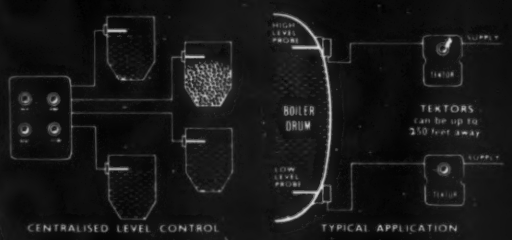

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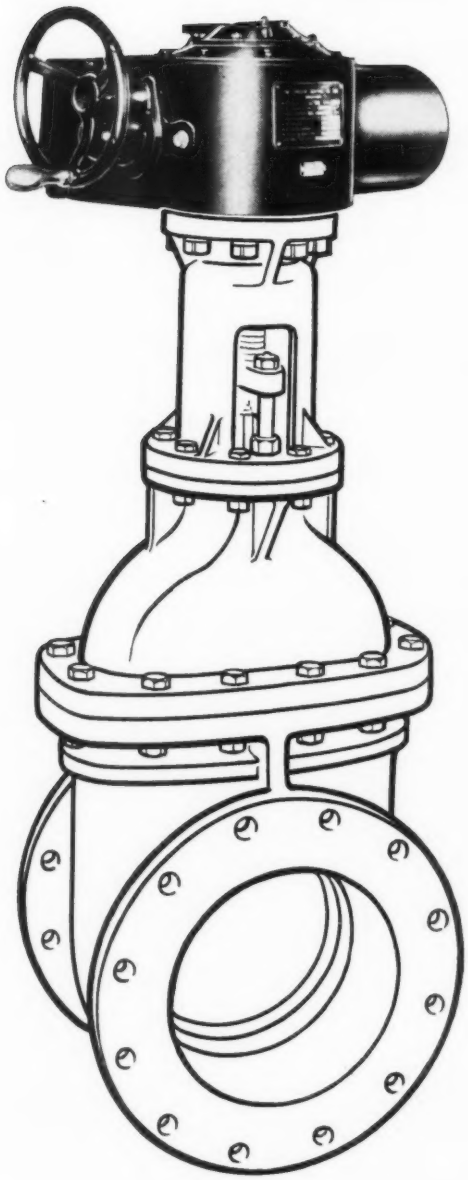

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AS.3A

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Britain's first two commercial nuclear power stations. ✳

✳ Both stations have been designed and constructed for the Central Electricity Generating Board by The Nuclear Power Group.

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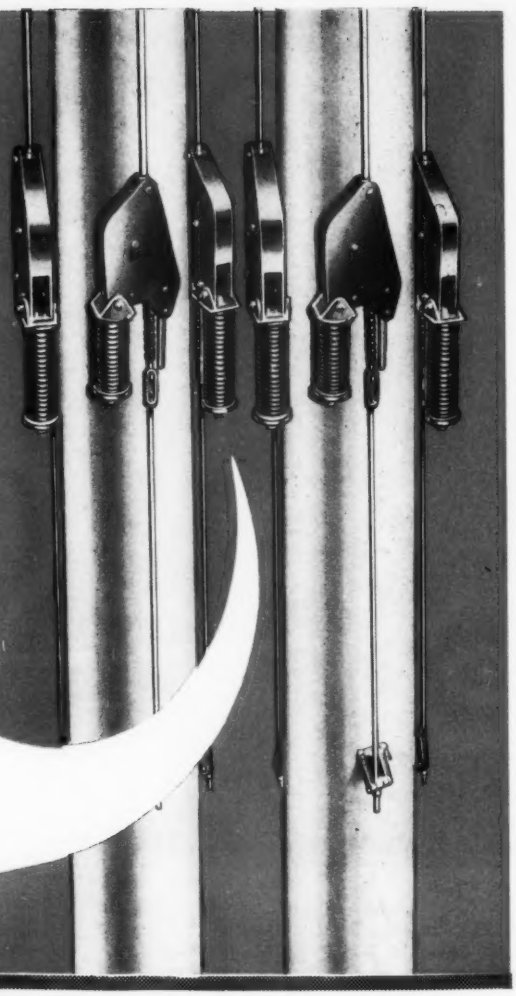

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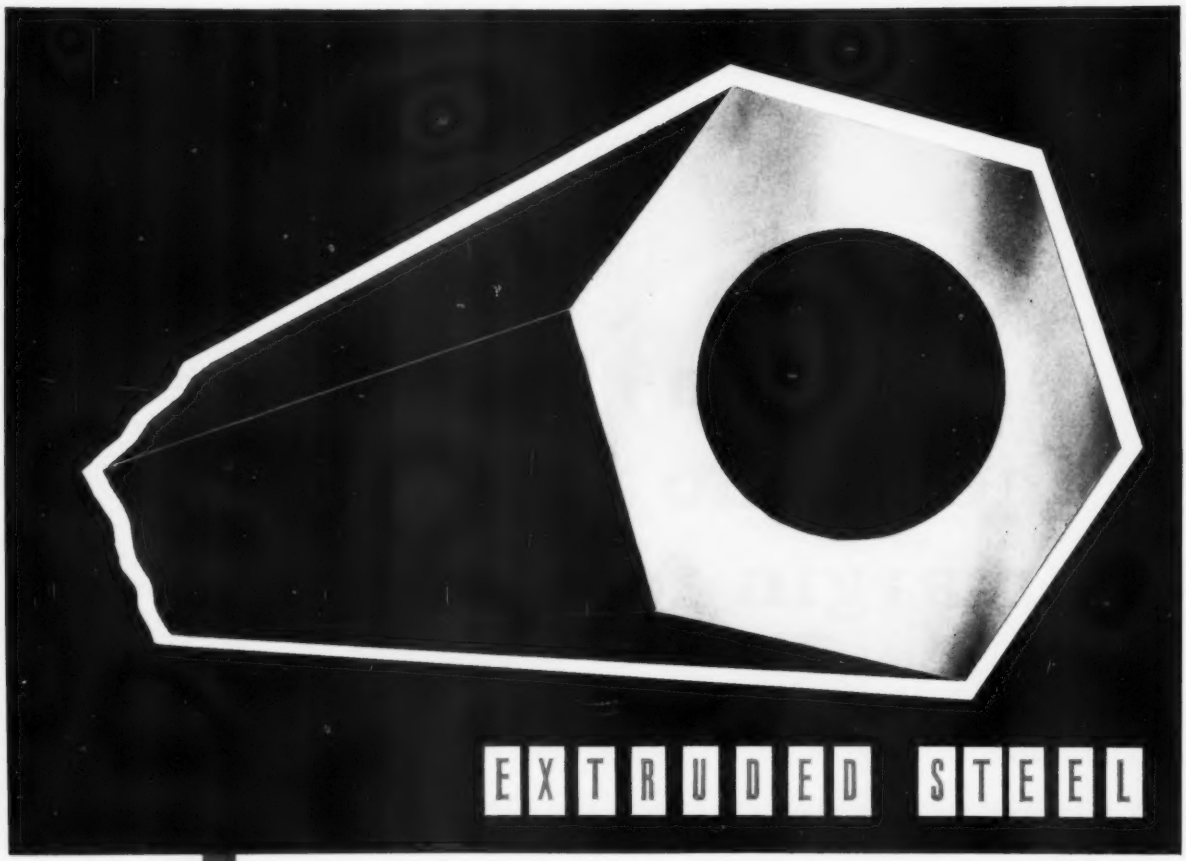

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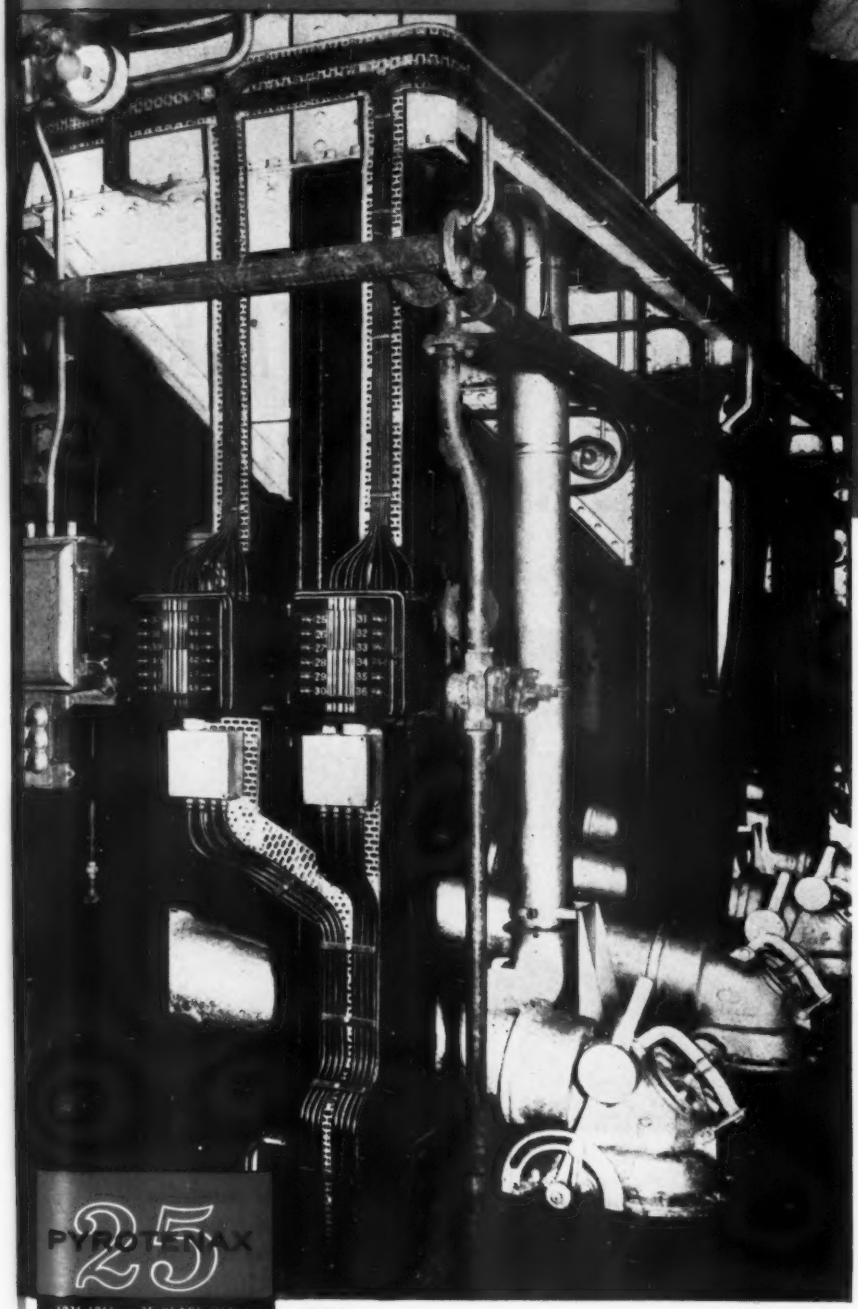

...there is something here for industry!

The top photograph, printed by courtesy of A.E.I.—John Thompson Nuclear Energy Company Limited, a Partner Company of The Nuclear Power Group, shows some of the 982 "Pyrotenax" Thermocouple cables being run off the No. 1 pressure vessel wall at Berkeley Nuclear Power Station.

The reasons that make "Pyrotenax" thermocouples an almost automatic specification for nuclear power stations are equally valid in many industrial applications, and the number of "Pyrotenax" thermocouples and ancillary cables being used by industry is rapidly increasing. The photograph on the left shows "Pyrotenax" compensating cables running from retorts to control panels at the Windsor Street Gas Works, Birmingham.

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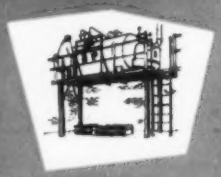
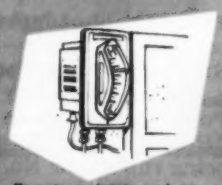
Installation's no problem. You need no special foundations, no plinths, no bolting down—just a flat floor that will bear 6 cwt./sq. ft. —the I.C.I. tank is supplied as a self-contained unit complete with chassis and, if necessary, can be easily moved.



If ground-space is scarce, the tank can be sited up to 20 ft. above floor-level.

Easy to operate — CO_2 is available at the opening of a valve, and the tank can be refilled without interrupting supply.



Easy to maintain and service — all parts readily accessible; for instance, the contents gauge can be serviced without emptying the tank.

I.C.I.'s Technical Service staff will advise on problems of CO_2 piping and metering. Tanks of larger capacity can be designed to customer's requirements.

ICI

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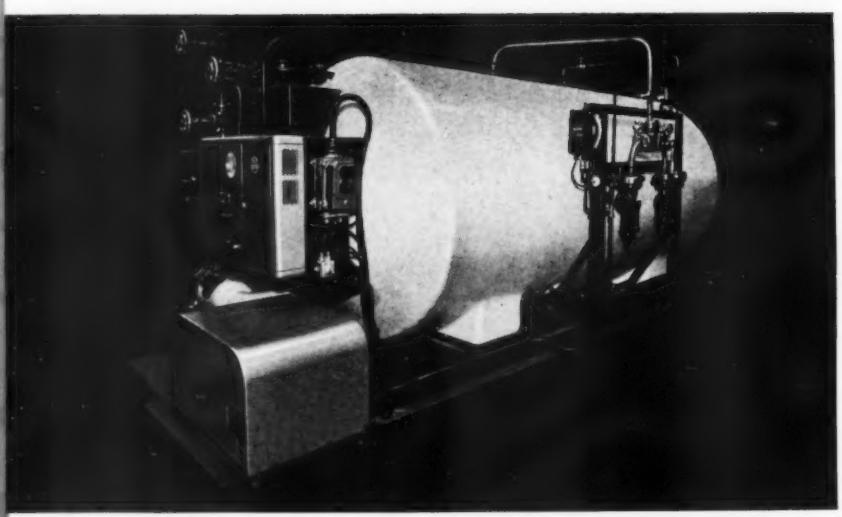
Even if you buy as little as 30 tons of CO_2 a year, the cheapest way of buying it is in bulk—and the best storage container is I.C.I.'s 5-ton liquid CO_2 tank. You'll need only 6 or 7 deliveries a year, and the tank will pay for itself in a very short time.

There's no problem in installing I.C.I.'s 5-ton liquid CO_2 tank—in fact, it can be delivered one day and in use the next. And I.C.I.'s Technical Service staff will supervise its start-up.

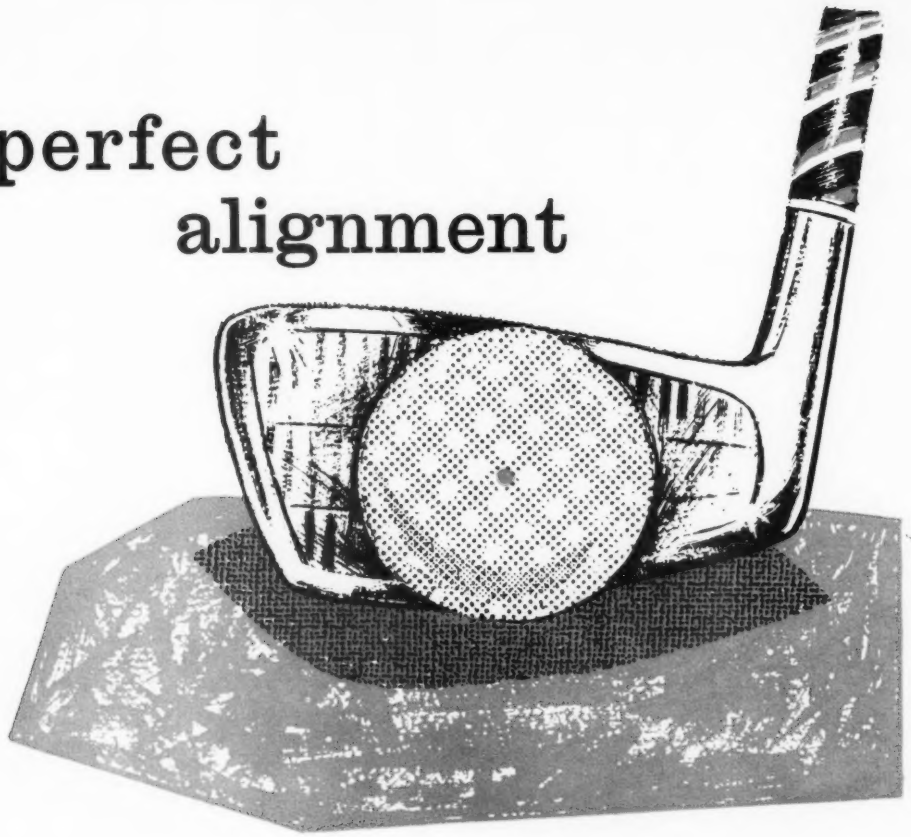
You'll find that for you, as for many other users, the I.C.I. liquid CO_2 tank will mean extra profit.

I.C.I.'s LIQUID CO_2 TANK MEANS TONS OF ECONOMY



If you'd like to discuss the economics of bulk delivery, or the installation of I.C.I.'s tank at your works—or if you'd simply like to read I.C.I.'s booklet on liquid CO_2 in bulk, get in touch with Imperial Chemical Industries Ltd., London, S.W.1.

perfect alignment



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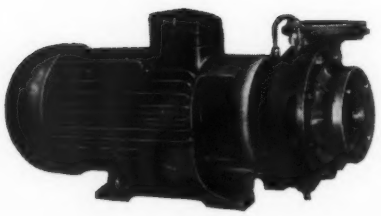

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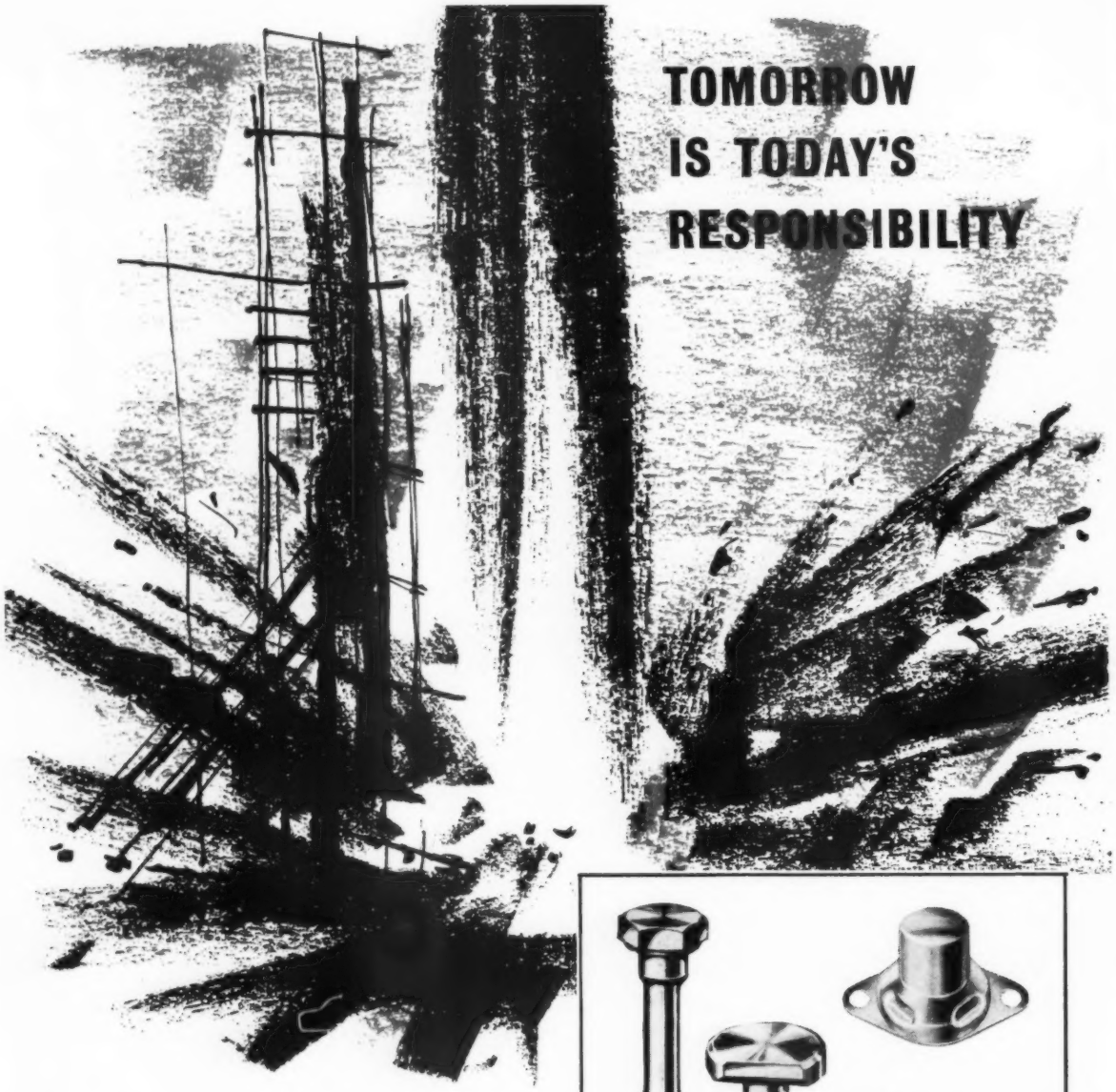

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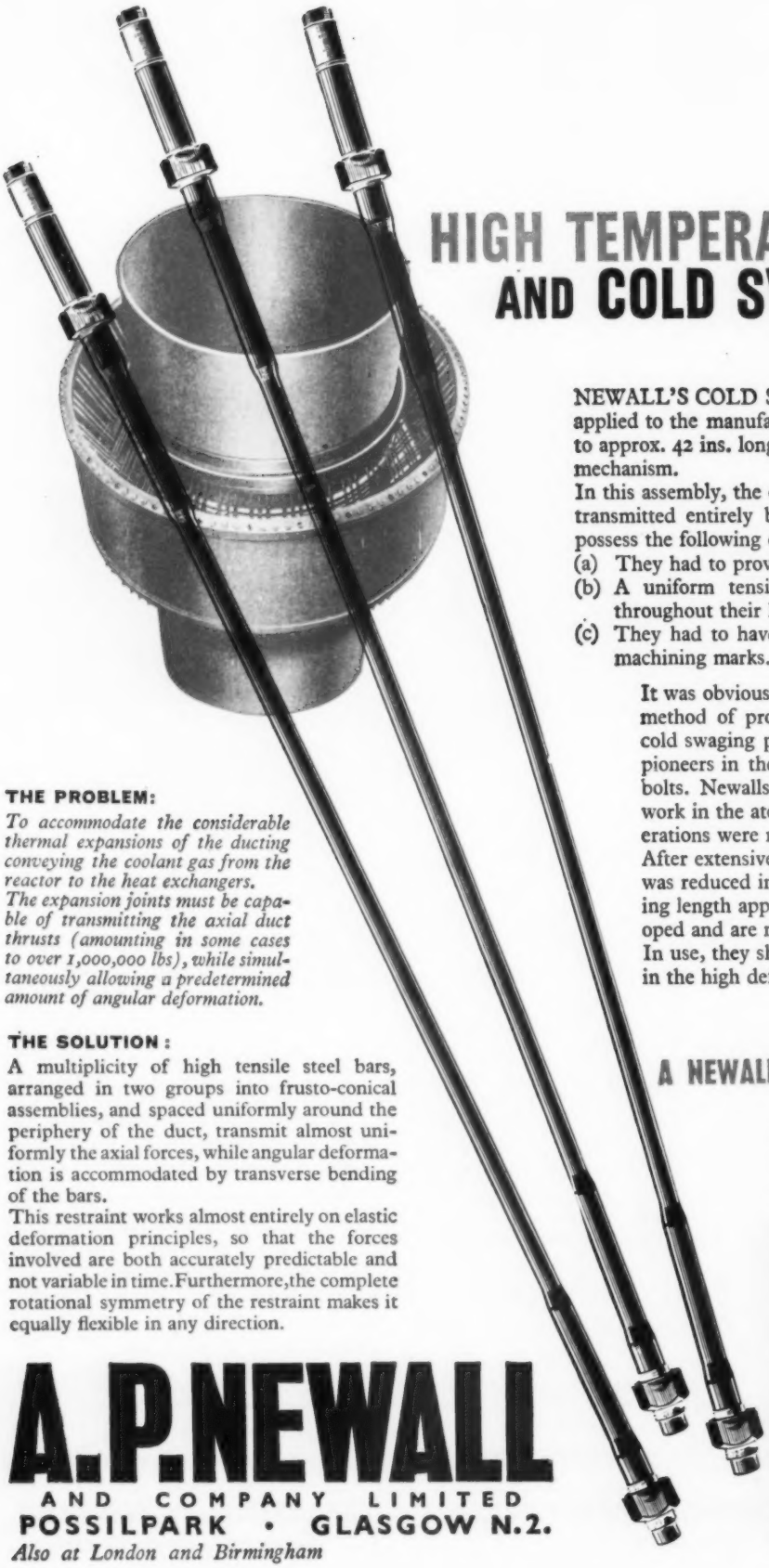


HIGH TEMPERATURE DUCTS AND COLD SWAGED BARS

THE PROBLEM:

To accommodate the considerable thermal expansions of the ducting conveying the coolant gas from the reactor to the heat exchangers. The expansion joints must be capable of transmitting the axial duct thrusts (amounting in some cases to over 1,000,000 lbs), while simultaneously allowing a predetermined amount of angular deformation.

THE SOLUTION:

A multiplicity of high tensile steel bars, arranged in two groups into frusto-conical assemblies, and spaced uniformly around the periphery of the duct, transmit almost uniformly the axial forces, while angular deformation is accommodated by transverse bending of the bars.

This restraint works almost entirely on elastic deformation principles, so that the forces involved are both accurately predictable and not variable in time. Furthermore, the complete rotational symmetry of the restraint makes it equally flexible in any direction.

NEWALL'S COLD SWAGING PROCESS was recently applied to the manufacture of high tensile steel bars (up to approx. 42 ins. long) for use in a new bellows restraint mechanism.

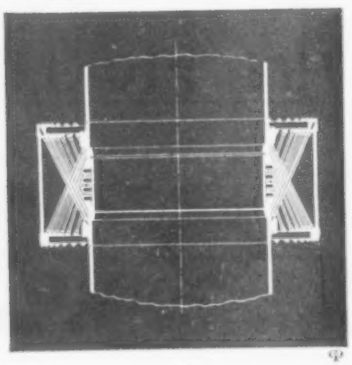
In this assembly, the considerable operating pressures are transmitted entirely by the tension bars, which had to possess the following qualities:

(a) They had to provide a high degree of flexibility.
(b) A uniform tensile strength of approx. 75 tons throughout their length was required.
(c) They had to have a surface completely free from machining marks.

It was obvious therefore that the most satisfactory method of producing such bars was by Newall's cold swaging process, as this company have been pioneers in the manufacture of swaged studs and bolts. Newalls were actually associated with early work in the atomic field when certain swaging operations were required in the planning of Harwell. After extensive experiments, during which a blank was reduced in diameter by approx. 30% (increasing length approx. 40%), the bars have been developed and are now incorporated in the mechanism. In use, they show "extremely high fatigue strength in the high deflection range."

A NEWALLASTIC PRODUCT

Below and at Top Left: Bellows Restraint Mechanism, designed by Richardsons, Westgarth & Co Ltd, for the Trawsfynydd Nuclear Power Station.



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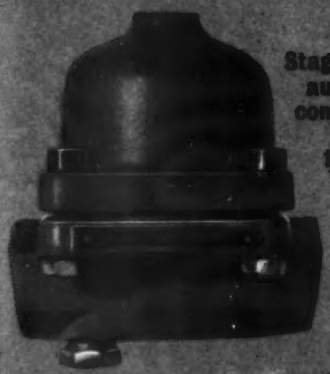

Stage-nozzle automatic condensate trap, flange fitting type I.K.

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NEL

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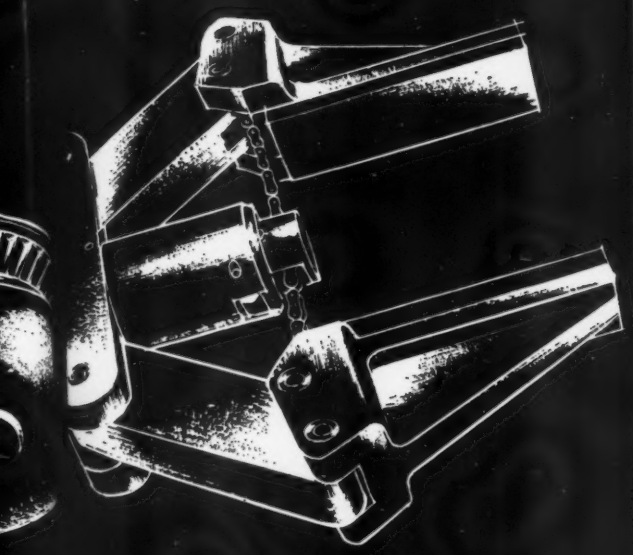
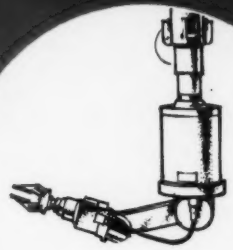
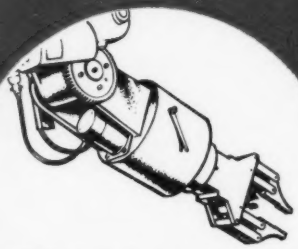
What makes the NEL Plans service so important? It includes complete and detailed preparation of layouts for any remote handling project. It enables you to build with confidence and to use the standard units in the NEL range, even for highly specialised needs. NEL have already planned the layouts for 'hot cell' handling equipment for some of today's most important nuclear projects. Use this service to back *your* plans—and use it as early as you can.



NE8 For lifting and handling R-A materials weighing up to 7lb. The equipment has power driven side-swing movements.



M300 General purpose mechanical arm for items from a few ounces to 750lb

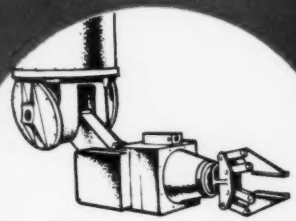


M100 Complete, low-cost system ready for installation. Full cell coverage and 200lb lift

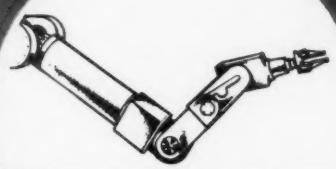
M150 Provides maximum manipulating versatility in minimum space, e.g. Alpha-Gamma handling in a sealed dry box.

Technical literature on all these types is available from NEL.

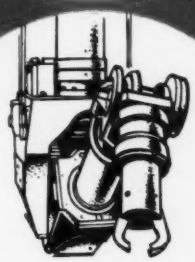
Eight standard mechanical arms are provided in the range, with electric drives, variable speeds, finger-tip controls and automatic connections for power tools.



M500 A medium-sized arm that can handle loads up to 2,000lb with a fine degree of control.



M550 Provides wide versatility in heavy load handling. Handles 100lb cantilevered 18ft with proportionately higher loads as moment is reduced.



M700 Heavyweight unit. Its rigid hook attachment can handle loads up to 5,000lb.

TGA RH11

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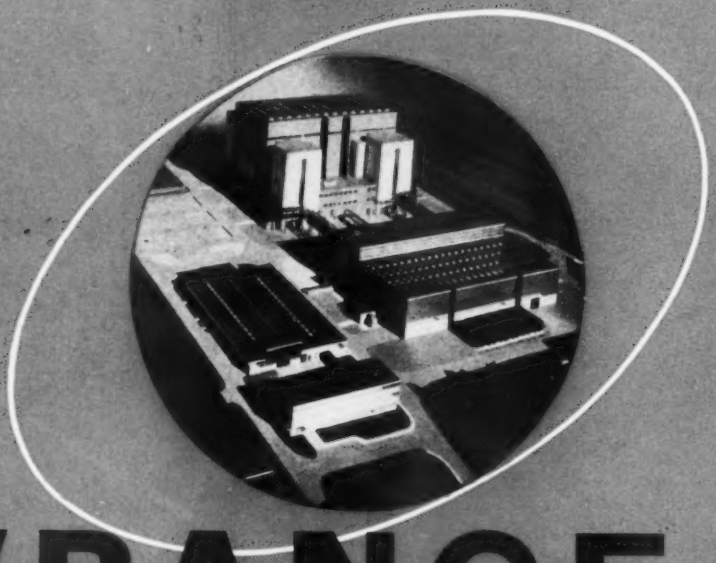

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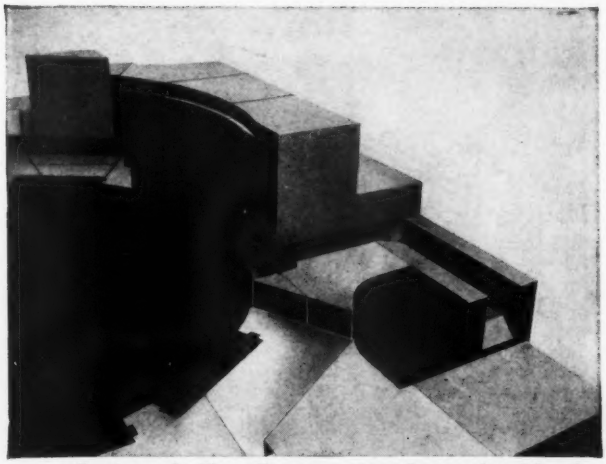

Sections of a "Jason" reactor recently completed for the Hawker-Siddeley Nuclear Power Co. Ltd.

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Smee's

Nuclear Power SEPTEMBER 1961 VOLUME 6 NUMBER 65

VIEWPOINTS letters to the Editor

Support for Atomic Forums

SIR: The phrase 'Atomic Industrial Forum' is now appearing as almost a household saying in the sphere of nuclear engineering—except in the United Kingdom. There are now almost a dozen established national Forums throughout the world, each one helping to further their country's status in the nuclear field, quite apart from improving relationships between the individual manufacturing concerns who compose the forums.

It is worth noting that the majority of these forums are in countries which are relative newcomers to nuclear engineering, and in general they are successful in providing information on nuclear developments to their members.

With the present deliberations on whether or not this country should become a member of FORATOM, surely the formation of a United Kingdom Atomic Industrial Forum would be a step forward, particularly as this country is recognised as one of the leaders in the technology of nuclear power reactors.

When the present glut of nuclear power station construction in this country slows down, the nuclear industry will be dependent more than ever on foreign orders, and accessibility to a well-organized Industrial Forum would appear to be beneficial to the members of the Forum, and also create greater confidence in the minds of potential customers.

A. D. WORDSWORTH

Strood, Kent.

How do other readers feel about this?—Editor.

Nuclear Ship Propulsion

SIR: In your July issue under 'Viewpoints,' p. 49, Captain H. F. Atkins, in discussing the nuclear ship delay, states: '. . . a General Dynamics' version using a closed-cycle gas turbine is not suitable for nuclear merchant ships.' Why?

Having read many books and papers (including Mr Brown's report on the MGCR), I know that the direct gas reactor, gas turbine marine nuclear propulsion plant is a more formidable task than it appears at first glance, but it is not an impossible one.

So I admire General Dynamics' decision to build a land prototype because I am convinced that the best way to solve one particular problem of this nature is to try it in practice. This is particularly so in Great Britain where the AGR is on the point of building.

CANTAMESSA GIUSEPPE
NAVAL ARCHITECT

Via Milano 20
Savona, Italy

French Fuel Fabrication

SIR: We read very carefully the editorial you published in your June 1961 issue, page 51, under the title 'Euratom and UK Fuel Exports.' In the paragraph 'French Competition' you speak of SICN at Annecy, which is perfectly correct, and you add: 'an additional plant is going up at St-Lobes in the Gironde that will have an estimated output of 250 tons by 1962 and of 400 tons by 1964, but the fuel elements to be produced are for heavy water reactors.'

Such a plant will not belong to SICN, but to our own society; our first intention was to build it in St-Loubès as you said, but we changed our mind and the plant is now under construction at Romans, in the Drôme, near by the Rhône valley, about one hundred miles North of Marcoule. It is supposed to be in operation early in the year 1962. But, the important fact is that we shall produce there fuel elements for the graphite moderated and gas cooled reactors of Marcoule (CEA) and Chinon (Electricité de France).

We are planning a second step, one year afterwards, for the light and heavy water reactors fuel elements.

B. DE LASTEYRIE
DIRECTOR

Cerca
Bonneuil-sur-Marne (Seine)

Tokai Mura Test Plates

SIR: We are concerned with the following extract from a statement which appeared on page 56 of the June edition of your journal in connexion with the Tokai Mura nuclear power station: 'It has also been widely reported in Japan that cracks in test plates for the pressure vessel had been found and that the materials did not meet the Japan Industrial Standard. This was due to a difference in Lloyd's and Japanese standards'.

We would draw your attention to the facts of this particular case in that the plate material referred to was found defective by the Surveyors of this Society and was, in consequence, rejected on the basis of Lloyd's Register and not Japanese standards of acceptance. The Society has applied the same high standards to plate material used for other reactor pressure vessels built in this country and abroad.

R. W. CLARKE
for SECRETARY

Lloyd's Register of Shipping,
Land Division, Croydon

Registered Trade Marks

SIR: In your July survey of 'Pumps in Atomic Energy' you mention MONEL several times as one of the materials of construction employed. In the section on the products of C.T. (London) Ltd on page 69, MONEL is printed wholly in lower case type in exactly the same way as 'plastic'. The purpose of this letter is to draw your attention to the fact that MONEL is a Registered Trade Mark of our subsidiary company Henry Wiggin & Company, Ltd, and as such should not be used as a common name for copper-nickel alloys.

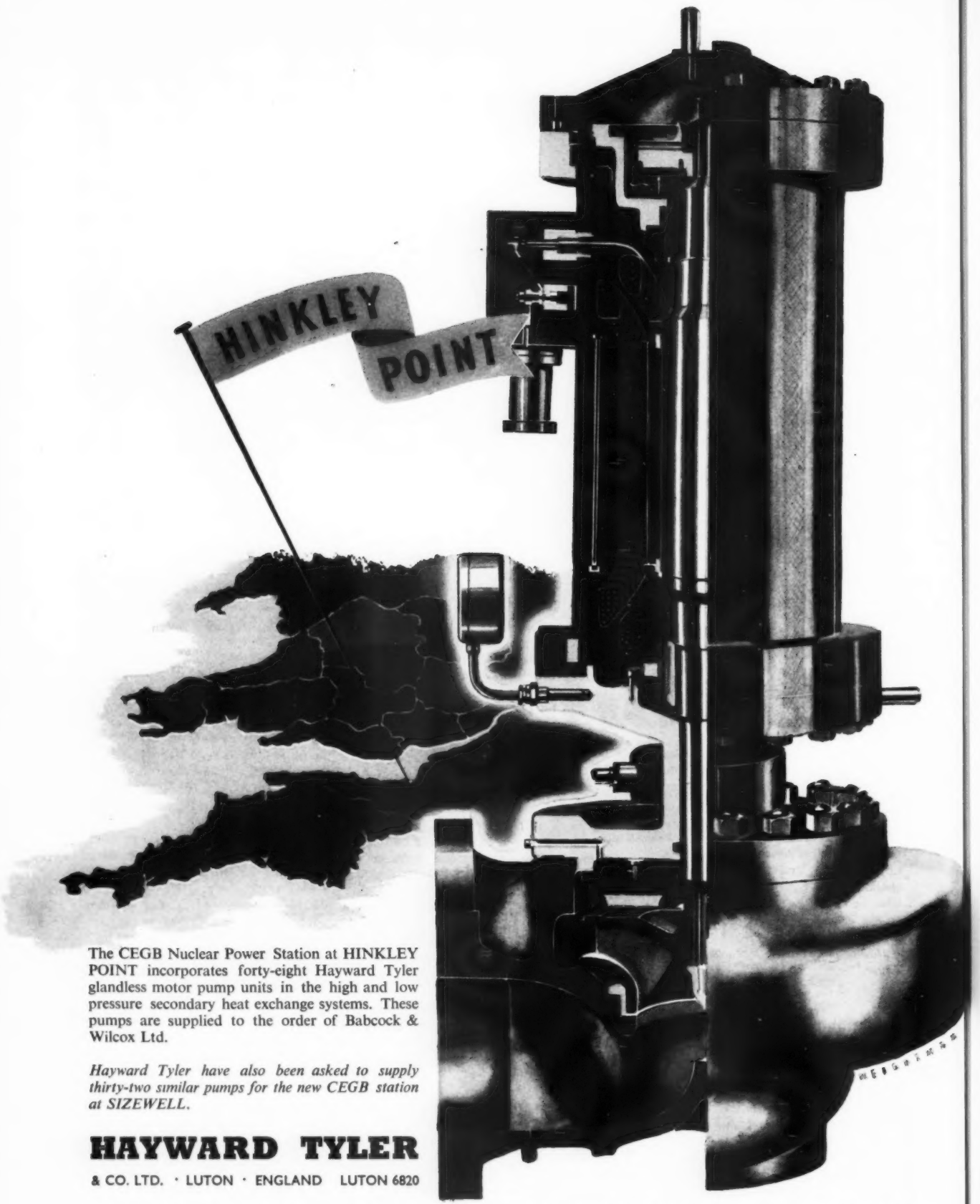
We should be grateful if you would ensure that on future occasions where the name MONEL or other Wiggin trade marks, e.g. INCONEL and NIMONIC, are used in your columns, either in editorial matter or in contributed articles, they are printed in a distinctive manner, e.g. in inverted commas or in capital letters to emphasize their special status.

J. H. ANSTEY
MANAGER
PATENT DEPARTMENT
The International Nickel Co (Mond) Ltd,
Millbank, London, SW1

On-Load Refuelling

Due to an error in the preparation of Mr K. Dent's paper (*August issue*) for the press, acknowledgements to The Nuclear Power Group for Figures 1, 4, 6, 7 and to Flight Refuelling Ltd for Figure 5 were omitted.

EDITOR



The CEGB Nuclear Power Station at HINKLEY POINT incorporates forty-eight Hayward Tyler glandless motor pump units in the high and low pressure secondary heat exchange systems. These pumps are supplied to the order of Babcock & Wilcox Ltd.

Hayward Tyler have also been asked to supply thirty-two similar pumps for the new CEGB station at SIZEWELL.

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OPINION

Cheaper nuclear power

THE SUMMER OF 1961 promises to rank as one of the more significant periods in the development of nuclear power. The list of potentially favourable events is formidable. Coming shortly before the fifth anniversary of Calder Hall has been the going critical of Bradwell—to be followed very soon by Berkeley; in addition, there has been the announcement in the United States that the Pacific Gas & Electric Company will build a 325 MWe boiling water reactor claimed to be competitive with comparable conventional power. This is a claim that has not previously been made and one which, because of a definite power cost estimate, must imply a comprehensive performance guarantee from the manufacturer, General Electric of the U.S.

In the United States, too, there has been the admission by the Yankee Atomic Electric Company that its estimates of capital costs have been too high and that the figure is 20 per cent less than forecast. As a result of this and an output 5MW more than expected from its pressurized water reactor, Yankee now indicates that costs from this demonstration plant will be 'a lot nearer to being competitive with conventional steam' than has been anticipated. (Earlier estimates were in the region of 11-13 mills from the first Yankee core against conventional station costs in New England of 8-10 mills). If this were not enough, General Electric of the US has followed up earlier claims by offering a full line of nuclear power plants rated up to 500MW which are expected to be competitive in the higher cost areas of the US. This offer is backed by firm prices and with a guaranteed output.

As for the United Kingdom, there have also been promising developments bearing on the cost of nuclear power. The encouraging performance of fuel elements in the lifetime of the first Calder fuel charge when only three elements out of 10,000 developed faults and only one fault was reported in the second charge, has been followed by the further news that fuel elements have achieved average exposures of 1000 MWd/t and some of over 3000 MWd/t in a later run; the high degree of reliability of Calder reactors has been established and their high load factor, despite shut-down for refuelling, established. The latest step is the submitting of tenders for Oldbury which incorporate prestressed concrete pressure vessels — a step hailed as the forerunner to cheaper nuclear power through higher pressures and efficiency.

Despite these events, the impression still persists that present and future nuclear power stations will be hopelessly uneconomic — an impression hardly discouraged by the Government's vacillations and statements over nuclear ship economics.

For this reason and because of developments to date, one could ask whether in fact the assumptions on which the future cost of nuclear power is based do not in fact penalize and depress the industry by being too conservative. Estimates of the cost of power from UK nuclear stations have always assumed a 75 per cent load factor. This is obviously a low figure in the light of Calder and Chapelcross availability (the eight reactors are now showing an availability of 85-90 per cent) and also the Pacific Gas & Electric's assumption of a 90 per cent load factor. Once Bradwell and Berkeley have overcome their birth pangs and their operating experience has been transferred to other stations, a higher load factor than 75 per cent should be achieved.

A more debatable reconsideration is the assumed life of a nuclear station. Here a figure of 20 years is taken which contrasts sharply with life of 30 years for all conventional stations. This difference has a marked effect on the costs of nuclear generation because of its higher capital cost and the heavy charge for amortization.

Other considerations which affect the cost of nuclear power are fuel prices, interest rates and fuel burn-up. For the last, it is assumed that a burn-up of 3000 MWd/t will be achieved. Though indications are that this total will be reached with something to spare, it will be difficult to base estimates on a higher figure until the first two stations have been operating for some time. It is hardly likely, however, that the new fuel reprocessing plant being built at Windscale is designed only to receive fuel irradiated at this rate. A figure of 4500 MWd/t is believed to have also been taken into account in the design.

The effect that reconsidering the load factor and life of a nuclear power station would have on generating costs would be considerable. Of more importance would be the pyschological effect on an industry beset on all sides by Jeremiahs. If, for instance, an availability of 85 per cent and a 30 year life were assumed, the cost of generation would be reduced by nearly 20 per cent. Another example, given by A. L. Shaw of The Nuclear Power Group, in a recent article, states that the present estimated cost of the Group's Dungeness station is about 0·6d./kWh, based on a 75 per cent load factor and a 20 year life. Raising this load factor to 90 per cent, he says, and assuming an economic life of 25 years, would result in the generation cost being lowered to 0·5d./kWh. He adds that there is no reason on the grounds of reliability indicated by experience at Calder and Chapelcross or of power system economics, to invalidate these interesting possibilities if the British power stations fulfil in practice their designed performance.

The total investment to date in nuclear power, including defence, is some £3000 million. With this to protect, ultra-conservative predictions about cost tend to have a bad psychological effect on future development. Considerable damage has already been done both by earlier too-optimistic forecasts and by later too-gloomy predictions; but an uplift in outlook would come about if, for instance, more play was made about such items as the latest nuclear stations being competitive with high efficiency coal stations being built on the same site or that when electricity produced at Dungeness is sent across the Channel, it will be the cheapest electricity in France.

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* **High accuracy.** Transmitted signal is within $\frac{1}{4}\%$. Indication is within $\pm$ 1%.

* **Exceptional readability.** Big $11\frac{3}{4}$" long concentric 270° scale can be read easily at 25-35ft. Yet case measures only $7\frac{5}{16}$" x $9\frac{3}{4}$" x $4\frac{1}{4}$".

* **Threshold sensitivity.** 0·1% of input span. Low-friction drive mechanism permits accurate handling of low-energy input signals.

* **Designed for easy maintenance.** Only 3 basic parts. A high quality encapsulated motion amplifier; single-packaged pneumatics . . . servo-powered follow-up and relay valve; interchangeable, time-tested actuating elements.

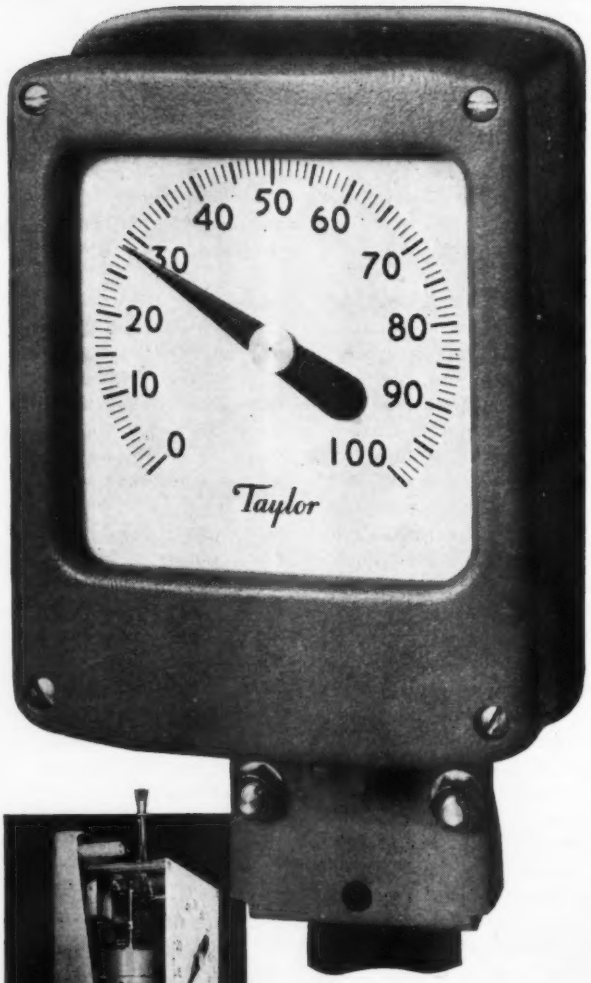
* **Lower inventories.** Benefits large users of instruments by utilizing actuating elements which are common with FULSCOPE and other Taylor indicating, recording and controlling instruments.

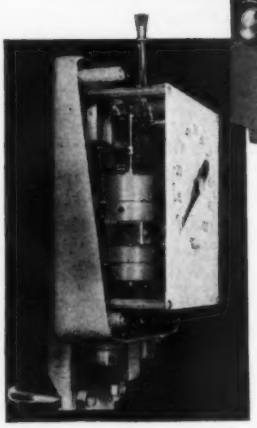
* **Conveniently calibrated.** Diagonally-split case makes all adjustments easily accessible by merely removing cover.

* **Weatherproof case.** Hammered grey enamelled finish on die-cast aluminium case . . . designed for field installation.

* **Adaptable mounting.** Universal bracket permits wall or pipe installation.

* **Non-indicating model (211T)** has same performance as 210T except for process indication.





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INSTRUMENTS OF THE FUTURE WILL HAVE SERVO-POWER—TAYLOR HAS IT NOW!

WORLDVIEW

the month in atomic energy

EUROPE

Bradwell goes critical, Berkeley close behind

Bradwell, August 19 Bradwell has beaten Berkeley in the race to become the first British commercial nuclear power station to go critical. Criticality was achieved here at 10.36 tonight during the loading of the 464th channel when a power of one watt was generated. When loading started on August 14, it was predicted that the No. 1 reactor would go critical when 474 channels were loaded.

In spite of the importance of the occasion, every attempt is being made to treat it as routine and neither the general manager nor the chief engineer of TNPG are present.

In charge of operations at that historic moment was A. R. Kirkpatrick, the Nuclear Power Group engineer (test controller) in charge. "Everything went according to schedule with only minor details to worry about", *Nuclear Power* was told. Some months of running trials of both the reactor and its connected generating plant will now take place before the station as a whole is connected to the National Grid.

Fuel loading was by hand and started at the central fuel channel and continued outwards, keeping a cylindrical pattern.

The fuel elements were lowered singly—eight to each channel—through three open standpipes by means of special hoists to a team at the top of the core. Using special hand grabs and friction pulleys, the team lowered the elements in their position within the fuel element channels of which there are a total of 3275 per reactor.

Site work at Bradwell started in January 1957 and the 300 MW station will be fully operational in 1962.

Berkeley loading Meanwhile, loading of the No. 1 reactor at Berkeley is continuing and "going to plan". Initially criticality is expected on August 22 or 23 against official predictions when loading started on August 12 of 14 days from that time i.e. August 26. Approximately 660 of the total 3,275 channels will be filled to reach this stage. This represents a weight of fuel loaded of about 50 tonnes compared with a total of 232 tonnes required to bring the reactor to the fully operational condition.

Britain applies for 'Six' membership

London The British Government has formally applied to join the European Economic Community. This move followed Mr Macmillan's statement in the House of Commons on July 31 and took the form of a letter, signed by the Prime Minister, to the Chairman of the Community's Council of Ministers.

The next stage is the passing of the letter to the European Commission at its next meeting, scheduled for September 5. Views will be expressed and the Council will consider these at its meeting later in September. Negotiations with Britain and the Six are expected to begin sometime in October.

Eire has formally applied for membership and it is likely that Denmark and Norway will also put in applications. Separate application has to be made to join Euratom and the Coal and Steel Community.

A statement from the Common Market Commission says it 'recognises, no less than the British Government, the extent and difficulty of the negotiations which are to be begun. For some months, the Commission has been studying the problems raised in the case of adhesion for Great Britain and for her various partners on the one hand and for the Community on the other. It is resolved to bring its full support to a positive solution of these problems . . .'

• **Hunterston pressure vessel** Successful completion of the stress-relieving of the first 70 ft diameter reactor pressure vessel at Hunterston nuclear generating station, Scotland, is reported by the General Electric Company.

• **Loan for AEG reactor** A loan of 16 million marks for the development of a super-heated steam reactor by Allgemeine Elektricitats-Gesellschaft (AEG) has been approved by the West German Atomics Minister, Dr S. Balke. Total cost of the project is put at 22·5 million marks. The Atomics Ministry say the reactor is a development of the Kahl boiling water reactor.

• **Fletcher joins UPC** P. T. Fletcher, former deputy managing director of the Development and Engineering Group, Risley, and special advisor to the AEA Member for Reactors, is to join the board of the United Power Company on October 1, 1961. He will be responsible for construction and supply.

• **New safety code** A safety code for workers exposed to ionising radiations in industry is laid down in the Ionising Radiations (Sealed Sources) Regulations, 1961, presented to Parliament on August 3. Most of the requirements come into operation in six months time but from August 15, the use of sealed sources in premises covered by the 1937 Factories Act has to be reported.

• **JASON'S future** With four weeks to go before the dismantling of Hawker Siddeley's JASON reactor, talks between HSNP, AEI and the Royal Naval College, Greenwich, are reaching final stages. If Treasury consent is obtained, AEI will probably instal the reactor for the Royal Naval College.

HUNTERSTON FUEL ELEMENTS Sir William Cook, Member for Reactors UKAEA, at the GEC nuclear research laboratories where he showed particular interest in the work being done on the stability and endurance of fuel elements. With him are Dr H. K. Cameron, Dr R. G. S. Skipper and Dr J. McNeillis and Mr P. A. Lindley. It was recently decided that the Hunterston fuel element will be manufactured to a design employing helical fins instead of straight fins, the AEA told *Nuclear Power* recently. This version has been adopted largely because of lower costs

WORLDVIEW

The AEA tests on-load refuelling at Calder

London Experiments to determine the effect of on-load refuelling and thermal cycling of fuel elements have been successfully carried out in the Calder Hall reactors by the AEA. These showed there was no significant effect on fuel elements as a result of on-load charging and that no measurable ill-effects were found after thermal cycling.

The experiment to determine the effects of thermal cycling, the AEA says, were carried out by oscillating two control rods up and down in the reactor core to produce temperature variations in the neighbouring channels. The oscillations were continued for approximately 13,000 cycles and the nearby fuel elements then discharged and examined.

These experiments were forecast in the AEA's seventh annual report when, among other points, it was said that severe thermal cycling might cause magnox cans to crack.

Swedes decide on BWR design studies

Stockholm Design studies on a 56 MW boiling water reactor are to be carried out by Allis-Chalmers Mfg Co. of the US for Aktiebolaget Atomkraftwerk under a recent contract award. Included in the contract is the preliminary design work for the proposed plant which would be built at Simpevarp, south of Stockholm (see *Worldview*, September 1960, p 85).

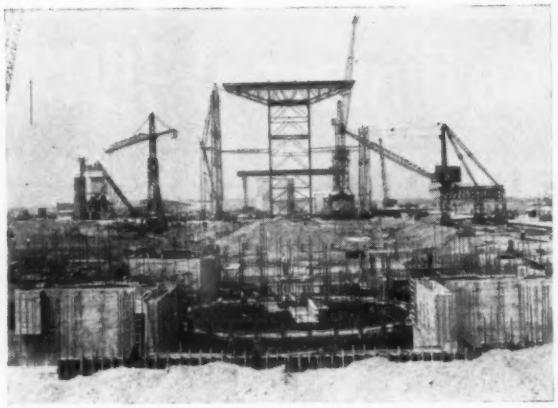
The studies for the Swedish company, an AKK Atomic Power Group affiliate, will be based on the installation of a direct cycle, natural circulation reactor rated at 173 MWt. Its fuel will be ceramic uranium oxide pellets (low enrichment) and the reactor will deliver dry saturated steam at 1250 psig, at a temperature of 574° F, directly to the turbine.

This new contract follows the recent announcement (see *Worldview*, July, p 56) that a technical evaluation of a 250 MW pressurized heavy water reactor is being undertaken by AB Atomenergi by Westinghouse in collaboration with the A. Johnson Co. of Sweden and the Betechel Corp. of San Francisco.

• **Foratom and the IAEA** The IAEA Board of Governors has decided to grant the Forum Atomique Europeen consultative status. The Japan Atomic Industrial Forum has also been granted similar status which entitles both bodies to certain privileges and facilities such as taking part as observers in IAEA activities and consulting with the Secretariat on matters of mutual interest.

• **Germany's nuclear ship** The first nuclear powered ship to be built by West Germany, is likely to be a bulk carrier of 15,000-16,000 dwt. A final decision will be made this winter, according to the company planning the building, Hamburger Kernergie-Gesellschaft.

DUNGENESS POWER STATION



Work at Dungeness is proceeding steadily and this picture of No 1 reactor shows the retaining walls above ground level and shuttering for the biological shield. In the background is the goliath crane and the construction area

Shown here are the excavation and foundations for the turbine house. In the foreground can be seen part of the excavation for the C. W. pumphouse and the inlet water culverts

Spectral shift plan studied for Halden

Oslo Plans are being studied to convert the Halden Boiling Water Reactor to an experimental spectral shift controlled facility. This would take place after completion of the present OEEC programme, the first quarterly report (January 1, March 31, 1961) on the activities of the Institutt for Atomenergi (IFA) states.

It says that an analysis of the economic aspects of the spectral shift controlled reactor concept has been carried out and a proposal for converting the Halden BWR has been evaluated. This modification would require a new core, and to get a better stability margin for the system, a new subcooler loop is needed.

The flowsheet for JEEP II was redesigned to suit even a spectral shift controlled reactor during the quarter. This followed a review to simplify the design of the reactor and bring down costs.

Work on nuclear propulsion continued with emphasis on boiling water reactor dynamics and hydraulics. Revised REDE-RIATOM plans now use a direct steam cycle with the coolant recirculated in two parallel primary subcooling loops, both incorporating a secondary steam generator.

A study of the application of nuclear power to an oceanographic research vessel was carried out and several novel features were brought into the design. Since it is anticipated that future atomic shipping will take full advantage of the highly concentrated energy represented in nuclear fuels, the report says, the speed of the vessel has been chosen unconventionally high. The reactor concept considered was based on the spectral shift control idea with in-core superheat and direct steam supply from reactor to turbine.

Plans and specifications have also been prepared for a 17,000 dwt nuclear powered bulk carrier for the proposed ENEA joint European nuclear ship development programme. An indirect dual cycle BWR, with substantial subcooling and forced circulation has been suggested as the power unit.

Sweden moves ahead on R4 station

Stockholm Planning work on the 365 MWt heavy water reactor for the Marviken Power Station proceeded steadily during the year; studies took into account on-load refuelling, the annual report issued by AB Atomenergi states.

The 100 MWe reactor (R4) will use natural uranium in the form of uranium dioxide clad in zircalloy. Heavy water under pressure will be used as the cooling agent, moderator and reflector. The plant is scheduled for commissioning in 1967.

During the first half of 1960, the two reactors R2 and R2-0 went into operation. Trouble with the tank for R2 resulted in the company being able to approve the initially delivered tank only for low-frequency operations. Preparations for replacing this tank are under way, the report adds. It will be supplied free of charge.

Work also continued on the 'homogenised' or cross-flow reactor. Tests have proved that this system reduces the necessity of auxiliary, control and protective systems. Furthermore, the risk of burning up the elements in event of a total stoppage in circulation is eliminated. A study has been started', the report continues, 'on short elements and fixed guide tubes based on the principle of split fuel elements which can be exchanged without the guide tubes having to be removed from the reactor.

'This would allow rearrangement in axial direction, improved burn-up and a lower height for the reactor tank, charging device and reactor vessel. This study might be of importance for the future design of reactors, possibly even R4. Up to now, findings have been promising and the study will continue with model tests'.

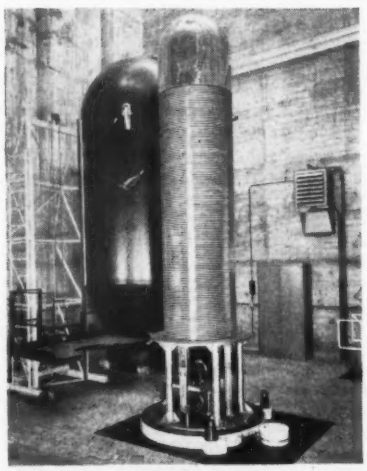
Other work being carried out includes that on a special laboratory building for isotope work; a preliminary study on a fast zero-energy reactor, FR-0, and the ordering of a pressurized exponential assembly for 1962 operation.

University reactor grants suspended 'temporarily'

London Three grants for university reactors have been suspended, the Department of Scientific and Industrial Research states. These were due to be included in the estimates of the DSIR for 1962–63.

The suspension is temporary for the Department says 'it is hoped the situation will be clear by November when the position can be reviewed again.' The nuclear reactors suspended were for the Scottish Universities, Liverpool and Manchester Universities and London University.

The disappointing announcement (see *Gracchus*, this issue) has come as a particular blow to Queen Mary College London, where negotiations and plans have been discussed for over three years.



ITALIAN ACCELERATOR Designed and built by scientists and technicians at the Centro Informazioni Studi Esperienze, (CISE) Milan is this 3.5 MeV Van de Graaff accelerator.

- **Italian power committee** A bill to set up a Power Committee of the Ministry of Industry and Commerce has been introduced into the Italian Chamber of Deputies. It proposes that the committee should be a co-ordinating and regulatory body.
- **Polish conference** About 40 scientists from the USSR, Poland, China, Czechoslovakia, Hungary, East Germany and Roumania took part in a six-day conference on cyclotrons and their applications in Krakow, Poland, recently.
- **Eurochemic construction** Building of its fuel reprocessing plant at Mol, Belgium, has been authorized by the Eurochemic Company. The principal specifications, based on plans submitted by St Gobain Nucleaire were approved last month. Cost estimates have risen and additional funds are to be sought from the shareholding nations.
- **Foratom conference** Discussions on the programme for Forum Atomique Europeen's 1962 conference in Paris took place recently. M Robert Gibrat, former president of ATEN, was elected president of the Paris Congress. The congress will be held in the second half of September and will last for three days.
- **New IAEA chief** Dr Arne Sigvard Eklund, director of Sweden's AB Atomenergi, has been nominated as the second Director General of the International Atomic Energy Agency to succeed Mr W. Sterling Cole whose four year term of office expires on November 30. His appointment has to be ratified by the annual General Conference which meets on September 26. The Board of Governor's choice of Eklund was over a Russian candidate, T. Sudjarvo, the Indonesian delegate on the Board of Governers.

Italy to process Elk River fuel

Rome Italian plans for the development of the thorium fuel cycle for power reactors has moved out of the research stage. A $1 million contract for the detailed design of a uranium-thorium fuel reprocessing plant to be built in Southern Italy has been signed by the Italian Committee for Nuclear Energy and Allis-Chalmers Manufacturing Company. Construction is to start within 12 months.

The plant is being designed to permit remote reprocessing of spent uranium-thorium fuel elements and also to enable the fabrication of new elements. Its design would permit the recovery of the uranium-thorium fuel materials from the Elk River reactor being built by Allis-Chalmers. In fact, the CNEN has obtained assurances from the USAEC that these elements will be available for reprocessing. The Elk River reprocessing requirements will just about match the capacity of this pilot Italian plant. There is at present no plant in the US suitable for reprocessing and refabricating Elk River elements.

The reason behind the joint Italian-Allis-Chalmers effort is the Italian belief that one of the best hopes of reducing the cost of nuclear power below that from conventional plants lies in the development of reactors using thorium-bearing fuels that are reprocessed after useful life in the reactor.

Most reactors in Italy work on the uranium-plutonium cycle and as a result, spent uranium-thorium fuel elements are not available in Italy for reprocessing. In the US, plutonium resulting from the uranium-plutonium cycle is extracted from the spent fuel and stockpiled. It is not refabricated. The same would be true of the Elk River elements but instead of stockpiling the uranium-233 resulting from Elk River, the AEC is sending the elements to Italy for reprocessing and refabrication.

AGR containment building passes tests

London Successful tests have been carried out on the 135 ft. diameter containment building which encloses the Advanced Gas-Cooled Reactor now nearing completion at Windscale, reports the AEA.

Very satisfactory results were obtained from sub-atmospheric, strength and leak tests. 'The pneumatic strength test at 12·5 lbs. per square inch (gauge) necessitated the diversion of traffic from the adjacent public road as a precautionary measure', the AEA report adds.

WORLDVIEW

Hawker Siddeley team breaks up

London In spite of the expressed intention of the Hawker Siddeley Group to help absorb people unable to find jobs now that its nuclear subsidiary at Langley is to close down, little enthusiasm has been shown by personnel at Hawker Siddeley Nuclear Power Co. Ltd to take up this offer. Many of the younger technicians and professional people have gone to firms outside the nuclear and aircraft engineering fields and for them, there has been no real difficulty in finding suitable positions.

The older and more qualified staff have had a much more difficult time. While there has been no shortage of interviews, when it came to the real test, prospective employers were not prepared to pay the money compatible with experience. Frequent official statements that there is a shortage of qualified technical and scientific men in the UK have become empty sounding phrases to these men, out of a job and looking for another one.

Apparently the demand for people of good calibre does not concern men over the age of 35. One great trouble is that industrial establishments, in spite of the lip service given to research and development, have very little money invested in a long-term programme. Practically the whole of their effort (i.e. the nuclear consortia) is directed towards the present building programme. Highly qualified people, experienced in forward thinking are therefore not wanted—in fact, the work is not there to justify their qualifications.

As for entering the scientific civil service or the nationalized industries, stringent grading rules prevent these men from entering at the level best fitting their qualifications. In some instances, ex-scientific civil servants have been offered grades lower than the ones they held, before leaving to go to industry. The older men have grown tired of the apparent lack of opportunity in the UK and have been looking overseas to the US and the Commonwealth. **Wilfred Smith,** Chief Project Engineer with a first class background of RAE and AWRE experience, is going to the Hong Kong University and **Gordon Metcalfe,** Chief Metallurgist, is looking to South Africa. Other people known to be going overseas are: **Neville Chrimes,** metallurgist, who is joining the Australian AEC at Lucas Heights and **Bruce Emmerson,** JASON supervisor, who is due to go to the Thailand AEC—this latter is a temporary appointment, however.

Senior people who are being absorbed within UK industry include: **Colin Hughes,** Chief Physicist, who is now with APC for Trawsfynydd commissioning; **M. G. Tennet,** physicist, and **Arthur Jones,** design engineer with AGR experience, also at APC. Both the Chief Chemical Engineer, **Les Clunn,** and **Julian Kemper,** Engineering Manager, are joining the A.P.V.Co. at Crawley. Other transfers to nuclear engineering firms are **Alan Russell,** head of the Project Drawing Office, who is returning to his old firm Parsons, at their Nuclear Research Centre, and **Ian Marshall,** engineer, who is going to Vickers-Armstrongs (South Marston) Ltd. Other people have gone into teaching, to management consultant firms, etc.

AEA provides Dragon fuel, interest free

Paris Fuel for the first charge of the Dragon reactor experiment is to be obtained from the UKAEA on an interest-free loan. Payment for actual burn-up will be made together with a contribution towards the processing costs, the second annual report on the OEEC High Temperature Reactor Project states. The report covers the period from April 1960 to March 31 1961.

Total expenditure for the year 1960–61 is estimated at £2,379,000 and the report predicts a budget for 1961–62 of £4,703,000. No change is foreseen in the total estimated expenditure of £13,680,000 during the five year life of the project.

Some of the changes noted in the report are the shortening of the fuel element spike and changes in the main shield plug, fuel boxes and fission product and helium purification plant. Also noted are the large numbers of problems being studied and a further collaboration agreement with the USAEC on exchanges of staff for extended periods.

MAJOR DRAGON CONTRACTS PLACED 1960/61

Contract	Contractor
Absorber rod drive for pressure vessels.	Société des Forges et Chantiers de la Mediterranee, France.
Airlocks and sealing doors for inner containment shell (subcontract).	Harland & Wolff, UK.
Charge/Discharge machine for fuel elements.	S.E.C.A., Switzerland.
25-Ton Circular Crane.	Ateliers Coupé Hugo, France.
Design and drawing office work.	C. J. Foote & Partners Ltd, UK. Hebron & Mediock, UK.
Inner containment shell.	Whessoe Ltd, UK.
Main civil and building work.	Turriff Construction Corporation Ltd, UK.
Mechanical services for reactor experiment.	Richard Crittall & Co. Ltd, UK.
Opening-up contract for site—civil engineering work.	Turriff Construction Corporation Ltd, UK.
Primary circuit dump tanks.	V.O.E.S.T., Austria.
Primary gas circulators.	Brown Boveri et Cie., Switzerland.
Primary heat exchangers.	Waagner-Biro A.G., Austria.
Prototype 37-way selector valve unit for sampling of coolant scavenge flow.	Plessey Nucleonic Ltd, UK.
Reactor pressure vessel.	Mannesmann-Export, GmbH, Germany.
Secondary heat exchangers.	Waagner-Biro A.G., Austria.
Electrical Equipment:	
415V airbreak switchgear.	English Electric Co. Ltd, UK.
Emergency supply alternator sets.	Brush Electrical Engineering Co. Ltd, UK.
11 kV 250 MVA switchboard.	Reyrolle & Co. Ltd, UK.
10·0 panel direct current air break switchboard and associated equipment.	Whipp & Bourne Ltd, UK.
Variable frequency generating sets.	Brown Boveri et Cie., Switzerland.
Electrical installations: reactor experiment (intermediate contract).	F. H. Wheeler & Co. Ltd, UK.
Graphite Components:	
Dummy fuel element, Mark I.	UKAEA.
Inner reflector.	UKAEA.
Outer reflector.	UKAEA.
Machining.	UKAEA.
Rods for control gear.	Morgan Crucible Co. Ltd, UK.
Static coil hysteresis clutch for charge/discharge machine.	Sperry Gyroscope Ltd, UK.
Structural steelwork for main civil building work (subcontract).	Modern Engineering (Bristol) Ltd, UK.
Temporary cranage for construction.	Constructors John Brown Ltd, UK.
Temporary electrics for construction.	T. Clarke & Co. Ltd, UK.
Thermal shield tanks.	Head Wrightson (Teesdale) Ltd, UK.
Upper and lower support structures within pressure vessel.	N. V. Neratoom, The Netherlands.
Upper steel support ring within pressure vessel.	Sheppard & Sons Ltd, UK.

OVERSEAS

India considers Candu station

Ontario A joint six months cost study which may result in India building a CANDU type nuclear power station is being undertaken by a team of ten Indian and Canadian specialists. The study is being made at India's request, Mr Gordon Churchill, the Minister responsible for atomic energy announced in Ottawa on August 4.

Cost of the project was given as $50,000 with work to be completed by the end of this year. Mr Churchill added that the study would determine the overall cost of building such a natural uranium, heavy water moderated plant and also the cost of components supplied by India and other countries. This would include Canadian uranium fuel.

The site is likely to be in northern India, in the East Punjab-Delhi area where the Indian Planning Commission has authorized the Department of Atomic Energy to search for a suitable site (see *Worldview*, August, p 58).

India is at present considering tenders for a 300 MW station to be built at Tarapur. These were due in on August 31 and were expected to come from the English Electric Company, a French consortium and the General Electric Company in collaboration with MAN of West Germany and the First Industrial Group of Japan.

Westinghouse test reactor under repair

Washington Recent repairs to the 60 MWt PWR Westinghouse Testing Reactor (WTR) were described by the manager of the project, Mr E. T. Morris to the AEC. He stated there had been objectionable vibration and acoustic noise present in the primary coolant system which was considered to be caused by the presence in the system of the seal tank weir. It had been planned to remove the seal tank and replace it by a simplified transition section during the scheduled reactor shut-down from February 16-22, 1961.

Mr Morris added that during the course of the seal tank work, it was determined that a revised method of supporting the surge tank diffusing cone was desirable so this was also undertaken and the work completed by March 20.

Subsequent flow tests proved that most of the vibration has been eliminated from the system by the repairs. However, some undesirable noise remained and further work to eliminate it will be undertaken during a future shut-down. These noises were associated with the main flow control valve. While it was believed that no serious effects were possible, it was felt that the noise level can and should be reduced.

Canadian nuclear accident

Toronto The nuclear research department of the University of Toronto was sealed off by police after an explosion in which two students were injured and taken to hospital. The explosion took place in the sub-critical assembly (using heavy water and natural uranium) when a test tube exploded. The assembly's cylindrical tank is 60 inches in diameter and 66 inches high.

GE offers competitive range of BWR's

New York A full line of nuclear power plants rated up to 500 MWe which are expected to be competitive in the higher fuel cost areas of the United States is being offered by the General Electric Co of the US.

The new plants, the company says, feature advanced boiling water reactor systems and carry nominal ratings of 100; 200; 300; 400 and 500 MW. They are being offered to US utilities at firm prices and with guaranteed net plant electrical output. With the exception of the 500 MW station, the new plant design eliminates the need for the containment sphere, the company adds.

Among the features of the new plants are cores of high density, steam separation within the reactor vessel and pressure suppression containment.

• **On-power refuelling** A contract for the design and development of an on-power refuelling machine to be used with pressure tube, heavy water moderated reactors, has been awarded to AMF by the USAEC.

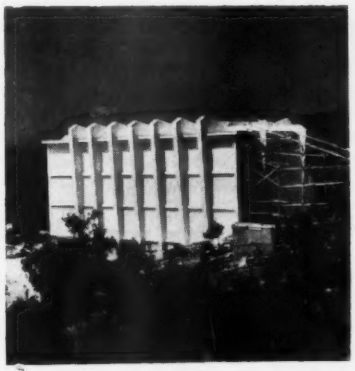
• **Nuclear rocket** Flight testing of a nuclear rocket could begin in 1966-67, Dr G. Seaborg, chairman of the AEC, told the American Ordnance Association recently.

• **Low 'Lenin' consumption** In 100 days of working at full capacity, the Soviet nuclear powered vessel, the *Lenin*, had used only about 20 grammes of uranium, Professor V. Yemelyanov stated recently, chairman of the USSR State Atomic Energy Committee.

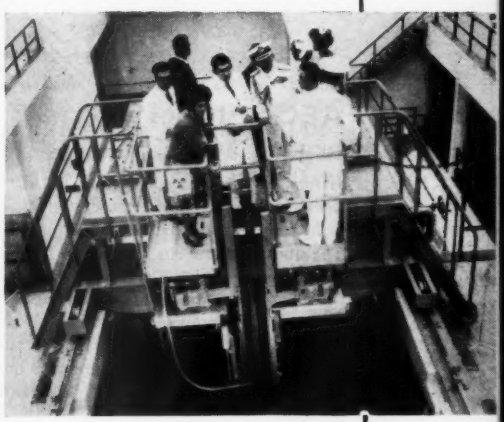
• **Reactor for Greenland?** Plans for a small nuclear power station near Godthaab in Greenland are currently under consideration, according to an official of the Greenland Affairs Department. No final decision will be taken until the autumn.

• **Research centre opens** A 1 MW AMF pool-type research reactor, the heart of the $2 million Western New York Nuclear Research Centre, has started operating at the University of Buffalo.

GREEK RESEARCH CENTRE



A view of the recently completed Democritus Nuclear Research Centre on the outskirts of Athens. It contains an AMF research reactor, and will have buildings for electronics and applied mathematics. The centre will be run by the Atomic Energy Commission of Greece



Queen Fredericka, left foreground, and King Paul I of Greece, inspect from the bridge their country's first research reactor. Explaining the reactor's operations to them is Dr N. Chryssochoidis, reactor supervisor

• **Heavy Water Components Test Reactor** The pressure vessel for the Heavy Water Components Test Reactor now under construction at the Savannah River plant has been placed into position, reports the USAEC. Construction of the reactor building and supporting facilities was said to be 75% complete and the reactor is expected to come into operation late this year or early in 1962.

• **UAR reactor inaugurated** Successful trials of the United Arab Republic's 2 MW Soviet-designed reactor at Inschass have been completed and the reactor was formally inaugurated by President Nasser early in August.

• **Vallecitos BWR change** Reporting on a proposed adjustment to its Vallecitos BWR, the US General Electric Co. told the AEC that the primary side of the VBWR steam generator had been isolated from its normal connexion with the reactor recirculation loop. The change had been made to permit continued operation during a study of the causes of a leak in one of the steam generator tubes, the company added.

WORLDVIEW

US moves on nuclear space propulsion

Washington The first phase contract to develop NERVA (Nuclear Engine for Rocket Vehicle Propulsion) has been signed by the AEC and Aerojet-General Corp. The subcontractor for the nuclear portion of the work is to be the Westinghouse Electric Corp.

NERVA is a follow-up to the nuclear rocket programme (Project ROVER) prototype reactors being developed at Los Alamos Scientific Laboratory.

The contract covers six months with continuation beyond that period based on performance. It will include the design of the NERVA engine, performance of work for LASL in the conduct of KIWI-B reactor tests, development plans and a cost schedule.

Further contracts connected with space flight have also been received by four firms from the National Aeronautics and Space Administration. These were made under the Reactor In-Flight Test (RIFT) programme and went to the Martin Co., Lockheed Aircraft Co., General Dynamics Astronautics and Douglas Aircraft Co.

These contracts also cover a six month period involving study of vehicle design problems in flight testing a nuclear rocket engine in the upper stage of a Saturn rocket booster.

Meanwhile, the first of a series of KIWI-B experimental reactors is scheduled to be ground tested in the autumn. This test will mark the start of a new accelerated testing phase in the nuclear rocket propulsion programme with facilities under construction at the Nevada Test Site able to permit power runs about every two months during 1962.

The KIWI-B1 reactor to be tested will use gaseous hydrogen as a propellant. A test of a similar reactor, pumping liquid hydrogen into the reactor system for the first time, is expected to be held early in 1962.

AEC reshapes internal organization

Washington Changes in the USAEC'S operating organization to increase efficiency have been announced by the Commission. The objects of the change are to: improve the organization's effectiveness; shorten the chain of command and communication with field operations; strengthen the role of the Operations Office Managers and also relieve headquarters programme divisions of administrative and supervisory burdens.

The management changes fall in three general categories: AEC laboratory programme direction; relationships between AEC headquarters and Operations Offices; alignment of functions at headquarters.

Congress again rejects Hanford conversion

Washington The House of Representatives has again rejected a Kennedy Administration proposal to convert the plutonium reactor at Hanford to produce between 650-760 MWe. The proposal was first denied on July 13 (see *Worldview*, August, p 58) but the Senate restored the cut and the proposal again came before the House.

The Republican Party successfully opposed the conversion plan on the issue of public vs private power (see *Gracchus*, August, p 60) and received support from some Democrats. The striking out of this project from the bill authorizing the AEC to build some $232 million worth of new construction may result in a revised bill being put before both Houses.

Saxton plant to start-up

Washington Approval for the proposed start-up of the 5 MW Saxton Reactor Facility, Pennsylvania, has been given by the USAEC's Advisory Committee on Reactor Safeguards. The reactor is a closed cycle, light water moderated and cooled pressurized water facility.

The Committee noted it was possible that the reactor could be made critical by the complete withdrawal of a single control rod. It added, however, that a system 'involving manually set limit switches is provided to prevent excessive rod withdrawal and to provide an adequate shutdown margin.'

The initial start-up programme was said to include operation of the reactor to a rated power level of 20 MWt. The reactor is being built by Westinghouse for the Saxton Nuclear Experiment Corporation.

• **US heavy water facilities** The AEC has granted permission for the Savannah River plant to perform heavy water reprocessing services for foreign reactor operators on condition that the heavy water was originally purchased from the USA. No commercial facilities are available to perform this service. Approximately 500 tons of heavy water produced at the Savannah River plant have been sold abroad since 1955.

• **Elk River pressure vessel cracks** A report presented to the AEC by Allis-Chalmers Mfg. Co. on cracks in the pressure vessel cladding for the Elk River reactor vessel says the cracks will not have any deleterious effects on corrosion of the base material, strength of the vessel or on the radioactivity levels in the primary loop. It is felt that cracking, which appeared at the surface following test pressurization, was caused by the release of locked-in stresses and originated at points in the brittle structure where small cracks or imperfections were present after thermal stress relief.

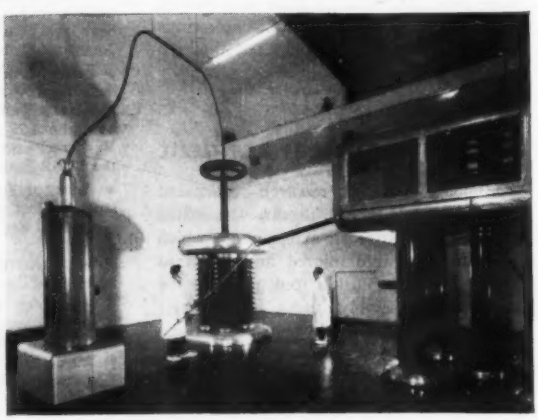
• **US information order** President Kennedy has issued an executive order giving himself power to veto any decisions by the Defence Secretary and the US Atomic Energy Commission to give nuclear information to foreign powers.

• **BONUS building ready** The containment building for the BONUS (Boiling Water Nuclear Superheat) 16·3 MW nuclear power station being built at Punta Higuera, Puerto Rico, has been completed and has been determined to be leakproof.

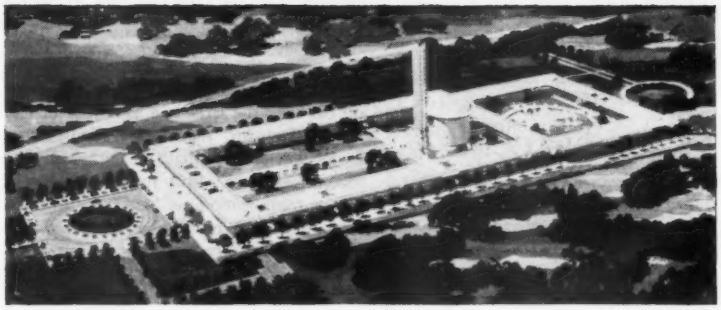
• **High Flux Isotope Reactor** Allis-Chalmers Mfg. Co. is to build the reactor vessel for the 100 MW Oak Ridge National Laboratory High Flux Isotope Reactor (HFIR). The $12 million reactor is expected to be in operation by 1964 and will be used primarily for production of transuranium elements for research.

• **Fuel element dejacketing** Mechanical dejacketing of fuel elements has been successfully carried out by Oak Ridge National Laboratory. Experiments involved fuel elements from the 20 MWt Sodium Reactor Experiment (SRE) at Santa Susanna. The process permits more simplified chemical processing for the recovery of unburned uranium, the USAEC claims.

• **TRIGA range extended** General Dynamics' TRIGA research reactors are now available with a new higher power rating of 250 kW for steady state operation, providing a flux of 10^{13}n/cm²-sec. They have also been added to the Vickers-Armstrong Ltd range.



HARWELL'S PROTON SYNCHROTRON Our picture shows (from the left) the 600 kV electrostatic generator, storage capacitor and high voltage cubicle associated with the 600 keV ion gun which supplies pulses of protons to a 15 MeV linear accelerator injector for NIMROD, a 7 GeV proton synchrotron to be completed in 1962



PAKISTAN NUCLEAR INSTITUTE A model of the new Pakistan Institute for Nuclear Science and Engineering to be built in Pakistan's new capital, Islamabad. The overall cost will be between $8-10 million, according to Dr I. Usmani, chairman of the Pakistan Atomic Energy Commission. A research reactor for the 16-building institute will be built by AMF Atomics

GE to build superheat reactor

Washington Permission to build the Vallecitos Experimental Superheat Reactor (VESR) at the US General Electric's Atomic Laboratory in California has been recommended by the USAEC'S chief hearing examiner.

The VESR will be a prototype superheat reactor to evaluate superheat reactor fuel and to gain information on operating and maintenance problems in the power conversion system. Financial support is being provided by a group of seven New York utilities which have formed a non-profit corporation, the Empire State Atomic Development Associates Inc. (ESADA). This group is participating as part of its nuclear research programme which will result in a 300–500 MWe advanced design nuclear power station in New York State (see *Worldview*, January p 59).

It is expected that the VESR will be the world's first superheat reactor and will be rated at 12·5 MWt. It will be light-water moderated and cooled by a combination of moderator boiling and forced convection cooling with saturated steam. Fuel will be U-235, 3·6% enriched, compacted to approximately 95% of theoretical density.

Indian Point core tested

New York Criticality testing of the $22 million core for the 275 MW Indian Point pressurized water reactor has begun at the Babcock & Wilcox Company's Lynchburg, Va., nuclear laboratories.

The test was said to be a 'pioneering accomplishment' in that it was the first time that a full scale power reactor core using a mixture of thorium and uranium oxides had been 'taken' to criticality.

The Indian Point station, being built by the Consolidated Edison Company, is at 275 MW, America's largest stationary nuclear power station. Part of the output will come from passing nuclear raised steam though a conventional oil-fired superheat cycle.

The plant will produce power, at a rough estimate, at 15 mills per kilowatt-hour, Mr J. F. Fairman, senior vice-president, told a recent AEC hearing on the Indian Point plant technical specifications. It is expected to go critical by the end of the year after design changes in the core, from metal plates to oxide rods with thorium, had caused some 12 months delay.

• **Enrico Fermi completion date** The USAEC has decided to extend until December 15 this year the time within which the Power Reactor Development Company (Michigan) might complete construction of its 100 MWe Enrico Fermi fast breeder reactor project. The company reports that non-nuclear testing of the plant is under-way and September 30 is given as the earliest date for completing these tests.

• **Savannah fuelling starts** The USAEC has authorized the fuelling and test operation of the *N.S. Savannah's* pressurized water reactor. Power operation will be at not more than 10% of full power until the vessel's transfer to York River, Virginia, where dock trials up to full power will be completed.

• **South African report** A nuclear power station is not expected to be built in South Africa before the late 1970's, according to South African sources. This is expected to be one of the conclusions of the commission of inquiry appointed in 1957 to report on siting and economics of nuclear power in South Africa.

• **No US help for India** The US Department of State and the Atomic Energy Commission have decided not to offer financial assistance towards the 300 MW Tarapur station India plans to build near Bombay, according to a report in '*Forum Memo*', Atomic Industrial Forum Inc's publication.

US Army builds floating nuclear power plant

Baltimore The US Army has awarded a contract for the design, construction and test operation of a floating nuclear power plant to the Martin Company. The 10 MW plant will be installed in the hull of a reconditioned and modified surplus Liberty ship and will supply electricity to military installations or port cities cut off from normal service by peacetime disaster or wartime action.

The contract provides that the design phase will be completed within 15 months. Subsequent construction and test phases will require an additional three years.

Floating power plants of conventional design with diesel and steam powered generators are in use today and were used during World War II and the Korean conflict. The nuclear plant will end the need for the fuel supply line which conventional floating power plants require.

AEC tests ramjet propulsion reactor

Washington The first successful test of a 'non-flying' reactor under the AEC's ramjet propulsion programme resulted in the operation of the TORY II A-1 reactor at 40 MWt. It was run for about 45 seconds at temperatures above 2000°F. Further tests will follow until the design power of 150 MWt is reached.

The TORY II A-1 system is a direct cycle, air-cooled reactor using highly enriched uranium homogeneously mixed with beryllium oxide. It went critical on December 9, 1960, and is the first of a series to be tested under the joint AEC-Air Force Project 'Pluto' programme. It is expected that a nuclear power source for ramjet propulsion would propel a missile at a speed three times that of sound for several hours. Thrust could only be achieved within the earth's atmosphere.

Soviet power growth

Moscow An 11% annual growth of power generation in the Soviet Union took place between 1954–1959, according to Mr I. Novikov, Minister for Power Station Construction. In an article in Pravda, Mr Novikov stated that during 1961, the Soviet Union would generate over 320,000 million kilowatt hours of electrical energy while the draft of the new (Communist) programme provided for a rise in power generation to 900,000–1,000,000 million kilowatt hours in 1970 and about three million million kilowatt hours in 1980.

Economic nuclear power stations would play a large part in the new programme. Future plans included power stations using new sources of energy and the direct conversion of thermal, nuclear, solar and chemical energy into electricity, the Minister added.

Cross Section by GRACCHUS

ONE OF THE ABJECT results of the decision to suspend grants for university reactors (see *Worldview* this issue) is that Britain will soon be the only major country without a university research or training reactor. The number of these reactors in the United States makes an obvious and shameful comparison; but even in smaller countries such as Holland and Yugoslavia (where two 15 kW reactors are being built) the need for this type of facility has long been recognized. For a nation classed as a leading nuclear power, this action, coupled with the waverings over a nuclear ship, must rank high on the list of pathetically short-sighted actions by officialdom and one which can only have adverse results on the future of this country. Happily, industry appears to have tired of this official inertia and is moving steadily towards setting up an industrial research facility centred round a Pye-built AMF reactor. The location of this centre is still to be decided but the south Midlands has been talked about as a possibility.

WHILE IT IS UNLIKELY that the nomination of Dr Sigvard Eklund as Director General of the International Atomic Energy Agency will be rejected by the General Conference which meets in September, there is increased speculation about the attitude the USSR will take. The Soviet Union proposed the Indonesian delegate on the Board of Governors for the post and by this probably induced a choice along political lines as it is known that they regard Dr Eklund highly. However, an article in the Soviet paper *Izvestia* by Professor Yemelyanov, chief Soviet delegate to the IAEA and head of the Soviet Atomic Energy authority, criticizes the Agency. He describes it as a parody on co-operation and comments that there was disappointment after the election of the first Director General, Mr Sterling Cole. This article comes after the Soviet proposal for a 'troika' organization or three member committee for the United Nations instead of a Secretary-General though no similar proposal is made for the IAEA.

EURATOM IS LIKELY TO give favourable consideration to the 25-30 MW BWR project which is to be submitted to it by the Italian Larderello company. This is a project for nuclear superheating aimed at upgrading the temperature of geothermal steam at the company's plant in Northern Italy. Mitchell Engineering, in association with AMF Atomics, are completing a design study—it was due to be handed in by August 25. This study is expected to confirm that the project is feasible and it is hoped that Euratom will be willing to take part financially. Should the Commission do so, it may raise problems for Mitchell's as present Euratom thinking is geared to placing as much work as possible within the European Community. Whether Britain's application to join the Common Market will make any difference, (for separate application has to be made to join Euratom) remains to be seen.

DUTCH MILITARY CIRCLES were thrown into some confusion recently when a casual check showed that the Dutch Army's central technical workshop at Utrecht was radioactive. A more thorough investigation showed that this radiation had come from a fluorescent paint containing radium which was being used on speedometers, compasses and other instruments. Use of the paint has now been banned and the Army say the degree of radiation did not exceed permissible levels.

FOLLOWING THE NEWS that the Soviet designed research reactor in Egypt is now in operation (see *Worldview* this issue) come rumours that Egypt is planning to build a 80-100 MW power reactor. As I understand it, the cost of this project is put at some £12 million though nothing definite has yet been published. Earlier this year, when the uproar over the Israeli 24 MW reactor had not died down, there were reports that Egypt was considering a heavy water type reactor. However, little further developed. The current rumour is based on a report that a party of West German experts will be visiting the country to discuss the setting up of a nuclear power station.

EUROCHEMIC HAS NOW gone far towards solving its financial difficulties. With the exception of one country, all the members have agreed to contribute more. A total of $30·5 million was required and as contributions came to $28·5 million, it was agreed that work should go ahead. Belgium, despite financial difficulties precipitated by the Congo troubles, has given more than any of the others. The surprising stumbling block proved to be Italy whose previous thinking and actions have been very European in outlook. It was Italy, for instance, whose behind-the-scenes activity played a major part in pushing through the recent Euratom special aid programme for power reactors. Over Eurochemic, however, the Italian feeling was that it should remain a research project and not develop into a full scale fuel reprocessing plant. Contributions, Italy thought, should remain at the original level to make a total of $12 million—a factor which naturally would have resulted in the scaling-down of the Mol plant.

On record

'In my opinion, the project for the Hanford electric generating facilities is a sort of innocent bystander in a vicious effort of the private power companies to throw their weight around . . . The argument which goes to the heart of the matter is the fear of the private power companies that this project is a sort of "entering wedge" for other steam electric plants outside of TVA . . . I must say this Hanford project is being made the victim of one of the most outrageous lobbying efforts that I have ever witnessed . . .'

Senator Clinton Anderson, former chairman of the Joint Committee on Atomic Energy, in the Senate debate on the plan to convert the Hanford plutonium reactor to electricity production.

I hear that . . .

. . . the contract for graphite impregnation will be awarded in a few weeks by the OEEC Dragon project—possibly to a British firm (not Hawker Siddeley's, of course).

. . . the AEA has suddenly realised, some months after the event, that the graphite contract for Tokai-Mura will be awarded to the Pechiney Company of France.

. . . a new 'name' is being culled for Tokai-Mura. Because of the recent changes the Japanese are thinking of not calling it British-made but the British-French-Japanese mingled nuclear power station.

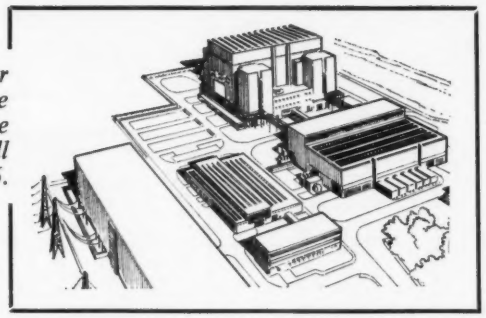
. . . the pilot irradiation plant at Hawker Siddeley's Langley works will be dismantled within the next six weeks and will apparently be consigned to the scrap heap.

. . . the AEA is considering licensing another firm to make package irradiation plants and at least one order for a plant is to be placed soon by a firm in the medical field.

. . . three oil companies are among the firms interested in the Pye-AMF project to build an industrial research centre (see *Worldview*, August, p 54).

. . . Soviet experts at the recent Industrial Exhibition at Earls Court claim that work on fuel elements has progressed to such a state that they have been able to run a reactor for over two years without refuelling.

The English Electric, Babcock and Wilcox, Taylor Woodrow Atomic Power Group began work on site for this £55 million power station in April 1961. The first reactor should be in operation in 1965 and full output capacity of 580 MW is expected in 1966.



SIZEWELL NUCLEAR POWER STATION

1. Optimization of the design

by H. S. ARMS, D.Sc., M.I.M.E., Chief Engineer, Atomic Power Division, English Electric Co. Ltd

THE DESIGN OPTIMIZATION of a large nuclear power station is not an exact technique, and by the very nature of the problem cannot produce a unique answer, nor can it produce any ' best ' answer. It is, of course, possible in theory to set up a group of mathematical equations which are related to the cost and performance of such a power station on the basis of current or assumed styles of design and costs and perhaps to solve these equations for a single answer; but such an answer is of little or no value. Any change in design or any error in assumptions immediately makes it incorrect. Such changes and errors are not avoidable. What can be done is much simpler and more valuable.

For each style of design of a large number of the features of a nuclear station it is possible to determine how, if at all, the cost and performance of the feature varies with change of the physical parameters which govern the operating conditions. With experience, it is possible to see which features react most strongly on the rest of the design and which features can be considered more or less in isolation. It is also possible at times to see which portions of the plant most influence the generating or capital costs of the station and consequently are worth most urgent attention from the designer or research worker. The fuel temperature, which affects the size and efficiency of both the reactor and the generating plant, is the classic case of this type.

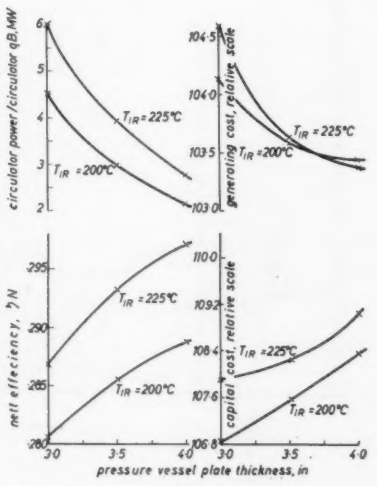
It is worth considering that many design or construction features which are known to be of major importance cannot be mathematically treated at all since the problem is too complex and the basic variables too imperfectly known, though here too an optimization type of approach is valuable. For example, it is not possible to tell by optimization whether it is better to construct a station using a Goliath type crane or some other style of heavy lifting arrangement.

In addition, an optimization study can be most misleading if the designer and the customer do not agree on the desirable characteristics of an optimum solution. For example, it will normally be found that the minimum of generating cost and the minimum of capital cost do not occur at the same value of a particular physical variable, and usually, that neither minimum is to be found at the point of maximum thermal efficiency.

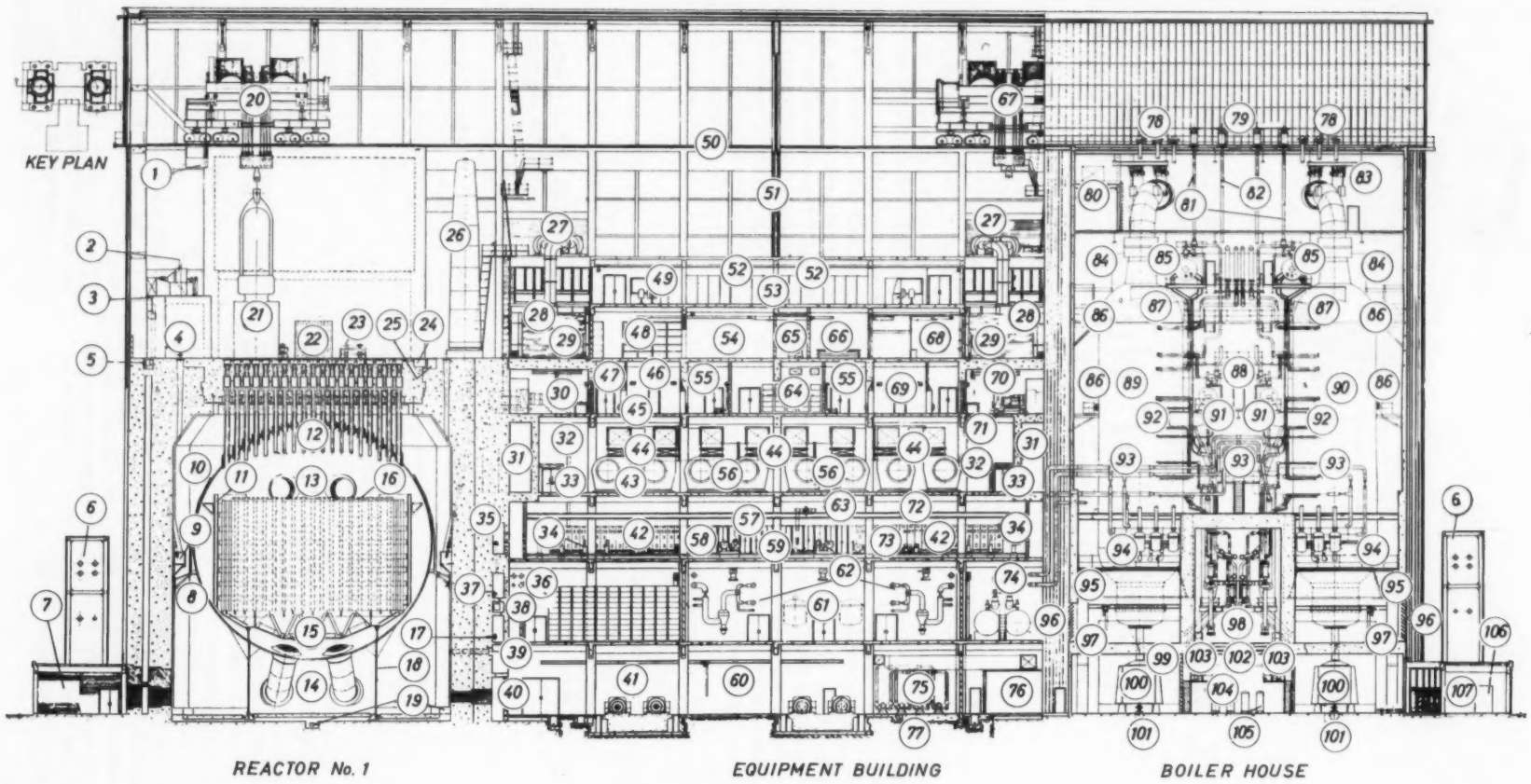
Of the variables which have no point of minimum cost size is perhaps the most important. Both generating cost and capital cost decrease, apparently without limit, as the output of a nuclear station is increased, and also as the size of the units of which it is built increases within the limits of feasibility, always assuming that each unit is running at its full capacity. It is trite but important to remember that a steam turbine running, say, at half its possible output is more expensive than a smaller turbine running at the same output. Since a change in the physical operating parameter will usually produce a consequent change in output it is important that scaling rules are developed so that all comparisons are made at the same net output. In the illustrations which follow this correction has been made.

OPTIMIZATION VARIABLES

Until recently for British reactors, it has proved to be worthwhile increasing the thickness of the pressure vessel



Effect on capital and generating costs of increasing pressure vessel plate thickness: parameters assumed constant were: number of ducts 6, rod. dia. 1·10 in, channel dia. 3·85 in, pitch 8·00 in. For reactor gas inlet temperature $T_{ir} = 200°C$ the centre channel ratting, (CCR) = 12·18 kW/ft, fuel peak temperature T_{sm} = 454·1° C; for T_{ir} = 225° C, CCR = 11·9 kW/ft, T_{sm} = 457·5° C, turbine exhaust moisture restricted to 40% (Fig. 1)



'Nuclear Power'

Cross-section through reactor building

1 crane cab; 2 centrifugal fan; 3 pilecap intake ventilation duct; 4 periscope viewing position; 5 amplifying gear for ion chamber; 6 steam pipes to turbine house; 7 construction access into biological shield void; 8 cowl support brackets; 9 ion chamber; 10 cowl; 11 core restraining structure; 12 stand pipes; 13 CO_2 outlet ducts; 14 CO_2 inlet ducts; 15 core support grid; 16 charge pan; 17 periscope position for mortuary void; 18 skirt; 19 shield cooling air inlet ducts to raft and side walls; 20 250-ton pilecap crane, 80-ton auxiliary hoist, No. 1 reactor; 21 fuelling machine; 22 built up opening for valve removal; 23 CO_2 valve operating drives; 24 air header trench; 25 b.c.d. equipment pipe trench; 26 reactor servicing machine; 27 centrifugal fans; 28 pilecap ventilation extract duct; 29 marshalling cubicles; 30 fuel preparation room, No. 1 reactor; 31 air duct from biological shield; 32 fan room; 33 decontamination room; 34 sector rod sets; 35 disposal chute to mortuary void; 36 pipes to boiler house (shown dotted); 37 periscope position for mortuary void; 38 mortuary void ventilation duct; 39 lower void periscope; 40 void main access; 41 diesel generators; 42 400V/444 cycles/s supply sets; 43 outlet ducts from filters; 44 dampers; 45 collector duct; 46 b.c.d. equipment room, No. 1 reactor; 47 routine detection units; 48 pile cap store; 49 control desk; 50 crane rail; 51 steel partition; 52 control cubicles; 53 pilecap supervision room; 54 air lock; 55 spare detection units; 56 centrifugal fans; 57 control rod motor contactor board; 58 safety circuit M.G. sets; 59 control rod machine floor; 60 maintenance space; 61 space for iodine filters; 62 CO_2 ancillary equipment; 63 2-ton crane; 64 sub-fuel store; 65 assistant engineers office; 66 pilecap operators room; 67 250-ton pilecap crane, 80-ton auxiliary hoist, No. 2 reactor; 68 pilecap change room; 69 fuel preparation room, No. 2 reactor; 70 b.c.d. equipment room, No. 2 reactor; 71 fuel transit magazine; 72 V.F. supply protection board; 73 contactor supply sets; 74 CO_2 economy tanks; 75 circulating water pumps; 76 sub-change room; 77 cable trench; 78 gas pressure relief valve discharge; 79 silencers; 80 shielded room for circulator emergency lubricating oil tank; 81 H.P. safety valve discharge; 82 L.P. safety valve discharge; 83 counter weight support; 84 shielded gallery; 85 H.P. steam drum; 86 gallery; 87 H.P. steam drum supports; 88 shielded gallery; 89 boiler No. 7; 90 boiler No. 8; 91 L.P. steam drum; 92 L.P. drum supports; 93 CO_2 circuit pipework, 94 gas pressure relief valve filters; 95 boiler skirt; 96 air intake louvres; 97 3-ton hoist; 98 circulating pump room; 99 fire protection wall; 100 main circulator motor; 101 auxiliary motor; 102 1-ton hoist; 103 hydraulic accumulators; 104 circulator motor house; 105 lubricating oil cooler; 106 control board; 107 main circulator instrument and control room

SIZEWELL PARAMETERS

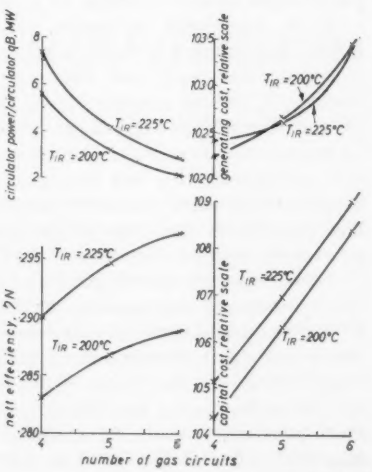
PERFORMANCE	
Number of reactors	2
Nett efficiency	30·51%
Nett sent out electrical	289·16 MW/reactor
Heat transferred to gas by reactor	947·7 MW/reactor
Heat transferred to steam in boiler	963·5 MW/reactor
Gross generated output	318·8 MW/reactor
Gross cycle efficiency (gross output/heat transferred to steam)	33·09%
Circulator power at generator terminals	21·94 MW/reactor
Auxiliary load (other than main gas circulators)	7·70 MW/reactor
CORE AND FUEL	
Weight of uranium	320·8 tonnes/reactor
Canning	Magnox
Weight of moderator	2237 tonnes/ reactor
Core size (not including reflector)	45 ft × 26 ft
Flattened radius	15 ft
Lattice pitch, square	8 in
Graphite channel diameter	3·85 in
Number of channels	≏3800
Fuel rod diameter	1·1 in
Fuel element length	41 in
Number of elements per channel	7
Number of control rods	99
Number of safety rods	8
Maximum can temperature, T_{sm}	453·7° C
Average centre channel rating	288·4 kW
Peak heat flux	15.3 kW/ft
Normal maximum uranium temperature (at channel irradiation of 1500 MWd/t)	575·5° C
Mean heat generation/max heat generation (radial)	0·8675
Mean heat generation/max heat generation (axial)	0·7178
Mean fuel rating	2·954 MW(th)/T
Max fuel rating	4·744 MW(th)/T
Mean fuel life	3120 MWd/tonne
Pressure vessel diameter	63 ft 6 in
Pressure vessel thickness	4⅛ in
BOILERS AND TURBINES	
Number of boilers	8
Boiler diameter	22 ft 6 in
Parallel length	62 ft
Total length	91 ft 6 in
H.P. drum pressure	720 lbf/in²a
H.P. superheater outlet temperature	398·8° C
LP. drum pressure	321·5 lbf/in²a
L.P. superheater outlet temperature	400·4° C
H.P. steam pressure at T.S.V.	661·9 lbf/in²a
H.P. steam temperature at T.S.V.	393·9° C
L.P. steam pressure at T.S.V.	291·2 lbf/in²a
L.P. steam temperature at T.S.V.	396·8° C
Vacuum	29 in Hg
Total steam flow/reactor	2·834 × 10⁶ lb/h
Ratio of H.P. steam flow/total steam flow	0·7544
Final feed temperature	120·6° C
Turbine exhaust pressure	0·539 lbf/in²a
Number of main turbines	2
Output of each main turbine	324·75 MW
CIRCULATORS	
Number of circulators	8
Type of circulator	Vertical, single stage axial with variable stagger inlet guide vanes
Drive	Vertical squirrel cage induction type motor
GAS CIRCUIT	
Reactor gas inlet pressure	278·8 lbf/in²a
Reactor gas inlet temperature	214·1° C
Reactor gas outlet temperature	409·9° C
Total gas flow/reactor	9854 lb/s
Total gas circuit pressure drop	11·09 lbf/in²
Pressure drop across reactor	5·32 lbf/in²
Pressure drop across fuel elements	4·30 lbf/in²
Centre channel mass flow at channel inlet	3·010 lb/s
Filtering and drying bypass flow, percentage of reactor gas flow	0·5
CIVIL ENGINEERING DATA	
Height of reactor building	192 ft
Length of reactor building	352 ft
Mean thickness of concrete main shield	5 ft 6 in
Mean thickness of concrete supplementary shield	5 ft
Distance across flats of main shield	72 ft 3 in
Height of concrete main shield	96 ft
Thickness of pile cap	11 ft 9 in
Foundation of reactor building	Reinforced concrete raft 228 ft × 106 ft × 8 ft thick
Turbine hall overall dimensions	Approx. 385 ft × 160 ft × 90 ft high
Pumphouse dimensions	125 ft wide × 133 ft long
Circulating water flow	27 × 10⁶gal/h

The figures given in this table are based on the maximum design fuel element temperature. Steam conditions for minimum design fuel element temperature are given on p.79.

steel to the maximum which general opinion in the industry, that is, the maker, the Atomic Energy Authority, the customer and inspecting Authority, considered safe. There are signs that this is no longer true for stations having an output between 500 and 600 MW. Figure 1 shows a set of curves prepared to investigate this point for Sizewell. In preparing these figures the parameters assumed constant were:

Number of gas ducts, blowers and boilers	6
Fuel element diameter	1·10 in
Graphite channel diameter	3·85 in
Lattice pitch	8·00 in
Turbine exhaust moisture	14%

The two values of the reactor gas inlet temperature, 200°C and 250°C, were used and for each of these inlet temperatures the derived values of fuel temperature and fuel rating were used. The pressure vessel plate thickness was the independent variable. Such things as ratio of graphite volume to pressure vessel volume were assumed constant. All other variables were derived or, where a choice was possible, assigned the most favourable value. These curves show quite clearly that as plate thickness increases blower power decreases and efficiency increases, as might be expected. Going from 3 in to 3·5 in, these effects lowered generating cost, but the increased capital cost of the thicker plate begins to counterbalance those benefits by the time 4 in is reached, more so in the case of



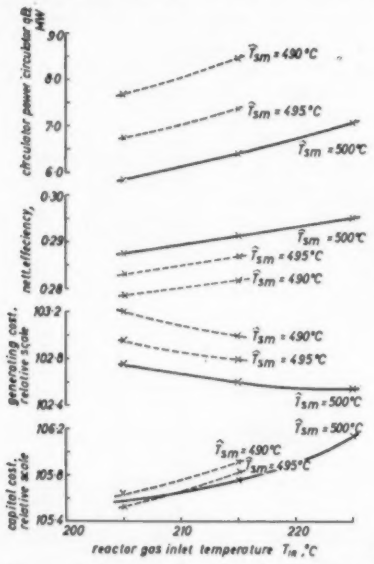
Steel cost savings due to reduction of number of gas circuits: parameters assumed constant; pressure vessel plate thickness 4 in, rod. dia. 1·10 in, channel dia. 3·85 in, pitch 8·00 in; for T_{ir} = 200° C, CCR = 12·18 kW/ft, T_{sm} = 454·1° C; for T_{ir} = 225°C, CCR = 11·9 kW/ft, T_{sm} = 457·5° C, turbine exhaust moisture restricted to 14% (Fig. 2)

'Nuclear Power'

200°C inlet temperature than for the higher temperature case. In both cases, however, a thickness of 4·5 in would seem to be beyond the economic optimum. The increase in capital cost arises largely from the extra weight of steel.

Figure 2 shows the results of saving steel by reducing the number of main gas circuits. There are also consequent changes in cost of civil works, switchgear for the electric blower drive and the like; but these are of less importance than the decrease in weight of steel.

In Fig. 2 it is quickly apparent that the loss of thermal efficiency and the increase of blower power required as the number of gas circuits is reduced is more than compensated by the saving in capital and the resultant decrease in generating cost. Even here, however, the generating cost curves are becoming flat enough to suggest that a reactor with less than



Effect of changing reactor gas inlet temperature for three fuel peak surface temperatures (Fig. 3)

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four main gas circuits may have to be of a modified design to make it seriously worth while adding the extra equipment necessary to ensure the safety of the system. (The assumptions used in deriving these curves are the same as for Fig. 1.)

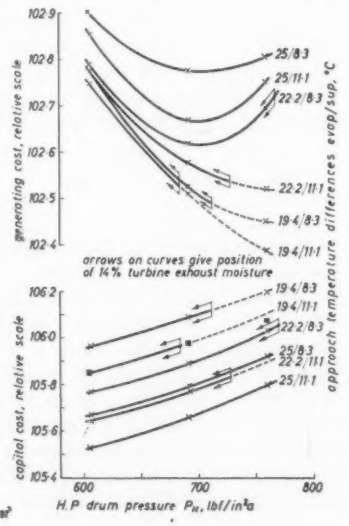
Also the power required for the individual gas circulators is now quite large and any very great increase in this power might require a change to a different type of drive.

Of the operational parameters, probably the mean fuel surface temperature and the reactor gas inlet temperature are among the most important. The mean fuel temperature is, however, a derived quantity where considerations of fuel life and of safety are paramount. Consequently, a peak fuel temperature is a more useful parameter when doing optimization studies since it is this temperature, in one variety or another, which limits the performance of the fuel elements. Fig. 3 illustrates the effect of changing reactor inlet temperature for three values of the fuel peak surface temperature. It will be seen that for this particular set of conditions the lowest generating cost is at an inlet temperature of about 220°C. This temperature has a considerable importance of its own as the effect of radiation on graphite, the storage of Wigner energy and the change of dimensions of the graphite with life in the reactor, are influenced by the temperature at which irradiation occurs. In addition, the ductility of the magnesium alloy of the fuel cans is strongly temperature-sensitive. The type of steam cycle used in the main turbines affects strongly the value of the optimum gas inlet temperature to the reactor. This is a particularly striking case of the fact that in nuclear work it pays to design the various major components in conjunction with each other.

Once a fuel peak temperature, fuel ratings and reactor inlet temperature have been chosen, the reactor gas outlet temperature is very nearly fixed. The temperature and pressure of the steam to the turbines, however, can be varied within reasonable limits. One of the major variations possible is concerned with the minimum temperature difference, the 'approach temperature', between gas and steam; another variable essentially concerned with the proportioning of temperatures in the boilers is the steam pressure. Figure 4 illustrates how these variables affect the economics of the station. With smaller approach temperatures in the boiler, the result is higher thermal efficiency in the cycle and larger heat drop in the turbines. If an attempt is made to reduce this difference too far, the extra cost of the larger boiler nullifies the benefit. The principal obstacle to high steam pressure in the dual pressure cycle used in Sizewell is the wetness this produces in the last stages of the turbine with consequent reduction in stage efficiency and increased erosion of the turbine rotor blades. In Fig. 4 the 14% wetness mark is given on several of the curves. Although the determination of allowable wetness is complex and varies from one size of turbine to another, 14% is about the maximum which can be accepted at present. A balance must be kept between the cost of large pipes to carry low pressure steam, and thick walled pipes and headers for high pressure steam. In this area the ordinary mechanism of optimization is not entirely suitable since different specifications and different design codes are used for pressures and temperatures at the extreme ends of the possible range so that a step function of cost can be introduced.

Of the remaining variables susceptible to optimization, the details of the fuel element design are perhaps both the most important and the most difficult to handle accurately. Of two basically similar designs, the fuel elements which are heaviest tend to cost less per ton, but since the temperature drop from centre to outside sets a limit on (channel) rating (which is nearly independent of fuel rod diameter) the thinner elements tend to be suitable for higher ratings per ton.

A conventional polyzonal helically finned fuel element with anti-rattle devices will be used. The core is roughly



Effect on costs of variation of H.P. drum pressure with approach temperature; feed temperature 129°C vacuum 28·9 in. Hg (Fig. 4)

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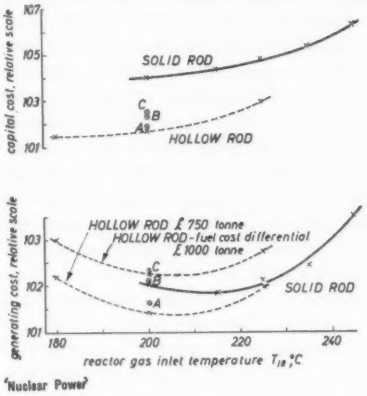
circular (45 ft dia. x 26 ft high) and will be built of octagonal graphite bricks located by a radially keyed system.

Figure 5 shows the results of attempting to use hollow rod fuel elements. In this element the uranium is hollow but is cooled only on the outside. There are many interesting technical features about the use of such a design which tends to demand higher gas pressure drop across the core for a given output than does a solid rod fuel element, but for the present purpose it is enough to consider the economic aspects. The curves show that for a typical pair of designs the use of hollow rod elements can save perhaps 2½% on the capital cost of a station. The lower curves suggest that if the cost of hollow rods is about £850 per ton more than the cost of solid rod fuels the two designs are of equal merit from the point of view of generating cost. For higher load factors than the 75% assumed in these curves the allowable cost difference decreases, and conversely for lower load factors. (For solid rod fuel elements a change of fuel price, other things being equal, of £200 per tonne is of about the same significance to a customer interested only in generating cost, as a charge of £1/kW installed on capital cost.)



Comparison of solid and hollow rod fuel elements; *A* steel end discs, *B* graphite plug, *C* steel end discs and graphite plug (Fig. 5)

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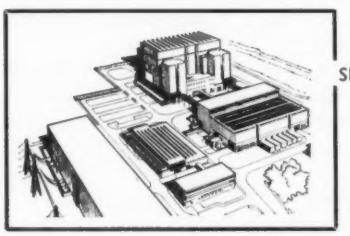
GENERAL

Many of the most important design features are not susceptible to optimization, for example, the bulk of the civil work. The cost of a road, or a fence, is not affected by steam pressure or fuel element diameter. It is sometimes possible to influence the layout of a station by considering the relative cost of power cabling and cooling water conduits; the cost of a deep turbine house basement can be balanced against a saving in cooling water pumping costs, but such opportunities are rare. More profitable is the search for fundamentally better designs or methods of construction. On the early designs of nuclear power stations there was a tendency to think first of the plant design and only later of the civil design. On Sizewell the concept of placing the two reactors in the same building arose from considering civil design and plant design together. The layout of the reactor itself was deliberately biased so as to keep the civil work as simple and clean as possible. This leads almost immediately to the idea of using one building for the two reactors. Another change which is of some importance is that the station control room is in the common reactor building. The cabling for the whole station is greatly simplified in this manner. When it is remembered that power cable and multi-core cable may cost on average about 15*s*/yd and that the total length on a nuclear station is many hundred thousand yards, such a feature is seen to be of interest.



SIZEWELL NUCLEAR POWER STATION

A demand for a change in station output is made directly to the reactor heat control system

2. Control and instrumentation

by D. MOORE, B.Sc.(Eng.), A.M.I.Mech.E., Head of Reactor Control Office, Control and Instrumentation Group, English Electric Co. Ltd.

THE FAVOURED SYSTEM of overall power control currently being proposed departs from practice on conventional stations which employ automatic boiler control, in meeting the basic functional requirements in the most simple and direct manner. Any changes in station output are initiated from the source of heat generation—the reactors. The overall system of control is required to:

(1) Maintain automatically the demanded reactor output, within the proposed flexibility range, irrespective of normal grid frequency alterations, keeping transient variations of reactor power and fuel element temperature, in particular, to a minimum.

(2) Respond to sudden large grid frequency changes, as might be caused by fault condition, by altering turbo-alternator output transiently in a sense to correct for these changes. Such a transient is to be sustained for the order of two minutes, and where the cause is a drop in grid frequency, will be available only if the station is not providing maximum turbo-alternator output capability.

(3) Be sufficiently flexible in design so as to allow sustained station output changes for sustained frequency changes from nominal, in the event of this being desirable for

Sizewell nuclear power station is designed for base load operation supplying 580 MWe to the grid system. The station operates normally with the steam systems of the two reactors ranged. Overall automatic power control is incorporated; the facility exists to engage those control loops needed according to the operating role. With full automatic control engaged experience may be gained of operation under non-base-load conditions. Control of reactor flux level and radial/azimuthal stability is automatic; long term reactivity variation due to xenon poison concentration changes and increasing fuel irradiation requires corrective action by an operator.

grid system control, and practicable for reactor operation.

A factor influencing the degree of automatic control engaged is the manner of plant operation. While base load operation will be the main role of the station in its earlier life, and the role for which it was designed, it is considered that a limited degree of output variation in response to signals initiated from its Grid Control Centre could be envisaged for the later life of the station, for effective control of the system. Such operation must depend upon the economics pertaining at this time, and will be influenced by accumulated experience of fuel element life under various degrees of thermal cycling conditions. The proposed overall control system is designed to provide for both operating roles.

Figure 1 shows in block diagram form a way the basic functional requirements, outlined earlier, can be met. The principle adopted is based upon a demand for a change of station output being made directly to the reactor heat control system. The turbo-alternators respond automatically to accept changes in steam generation and thus effect the desired alteration to the station electrical output.

The alternative, based upon conventional boiler control concepts, would initiate the change of station output required from the turbo-alternator throttle controls; in this case it is most likely that the steam pressure control systems would act upon the reactor gas mass flow control. This arrangement would not satisfy the stated functional requirements of the overall system so well, and results in more fuel element temperature cycling.

Reactor heat control

The reactor heat control loop (Fig. 1) varies reactor gas mass flow in response to an error signal between actual and demand reactor heat. The former is determined by a small computer from continuous measurements of gas mass flow and inlet and outlet duct gas temperatures. The loop demand may be preset by the operator as thermal power or he may engage the electrical output control. This loop compares the actual electrical output with an electrical output demand called for by the controller; any error signal sustained creates an automatic demand for a change in reactor heat output. Gas mass flow is varied by altering the stagger angle of the four circulators' inlet guide vanes, augmented by variation of the position of the four circuits' gas bypass valves. Over the prescribed range of mass flow variation, these actions are effected in a pre-arranged sequence.

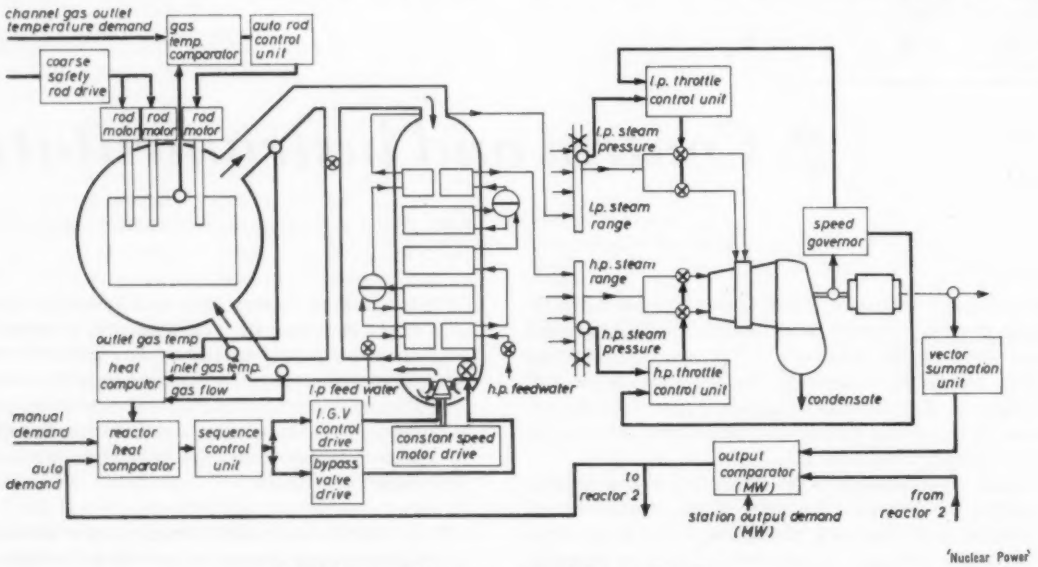
The influence of steam and feedwater conditions, and reactor gas outlet temperature, on the reactor inlet gas temperature may be controlled by allowing a proportion of reactor outlet gas flow to bypass the steam-raising units through the temperature control bypass valves. Each gas circuit includes such a valve. The ganged control of all four allow the operator to maintain design inlet gas temperature.

Reactor outlet gas temperature is controlled to an operator preset value by an automatic control rod sytem. The primary function of this loop is reactivity control, but it is a matter of design expediency that channel gas outlet temperature is chosen to be the controlled variable. This will be described further under the heading ' Reactivity Control.'

Turbo-alternator control

Control of each turbo-alternator's output is effected through three variables, H.P. and L.P. header steam pressures and turbo-alternator speed.

Similar H.P. and L.P. pressure control loops operate independently of each other on the respective H.P. and L.P. throttles of each turbo-alternator. The speed governor also

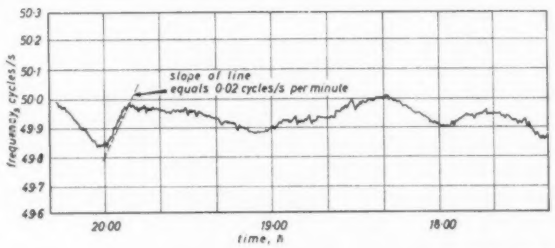


Block diagram of the station control diagram (Fig. 1)

acts upon both throttles; normally this reflects changes of grid frequency. In each control loop it is arranged that any variation between actual steam header pressure and a preset value, usually design, generates an error signal which causes the throttle to move in the direction to reduce this error. Interaction between pressure control loops and speed governor loop in respect of throttle movement is continuously present.

The main feature of this overall control system is the feed forward of steam header pressure signals to the turbo-alternator throttles, rather than a feedback to the reactor mass flow control. Furthermore, the critical issue of the whole concept lies in the design of turbo-alternator throttle control, such that the two functional requirements are met. To some extent these are conflicting.

At this stage it is worthwhile examining the nature of grid frequency variation that is anticipated. As a function of the present day methods of grid frequency control, variation occurs as a result of the inability to match exactly the supply to the transiently varying demand. It also occurs occasionally because of fault conditions. Analysis of anticipated frequency fluctuations may be derived from a study of frequency recordings; Fig. 2 represents a section of a recording chosen to demonstrate the nature of variations which can occur, but is not necessarily typical of any two hour period in 24 h. In general, in the absence of fault condition, variation is normally confined to $\pm 0{\cdot}1$ cycles/s about the nominal, and although the rate of change of frequency can be as high as 0·02 cycles/s per minute occasionally, it is not often that 0·1 cycles/s deviation occurs in less than 20 min. The sudden change of frequency shown on Fig. 2 is an example of this high rate of change which may occur several times a week. Continuous rapid variations, substantially random, also appear to exist;



Representative graph of the national grid frequency variation (Fig. 2)

clearly, these are of too high a frequency to be significantly reflected in reactor temperatures. Under a severe grid fault condition it is thought possible to incur virtually a step change of 0·2 cycles/s in frequency, or more.

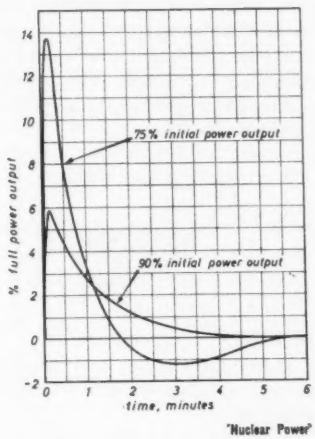
On the basis of this order of grid frequency fluctuation, the functional requirements are met by designing a rapidly operating turbo-alternator speed governor control loop, and comparatively slow steam pressure control loops, the characteristics of the latter being achieved by incorporating a suitably low open-loop gain.

An example of the transient variation in station output following a severe frequency variation is shown in Fig. 3, occurring from two steady state ouput levels. The magnitude of the effect is seen to be a function of original output level, and this is explained by the non-linearity of the turbo-alternator throttle characteristics. Under normal frequency variations, say less than 0·01 cycles/s per minute, there is no significant change in turbo-alternator output, nor in steam header pressures, and hence reactor temperatures.

FLUX SHAPE AND REACTIVITY CONTROL

Reactivity controlling systems may be considered separately from the power control systems, because they fulfill an essentially different function as a whole. Whereas power controls are concerned with the variation and utilization of total reactor heat generation, reactivity controls are directed towards maintaining the reactor in a stable critical condition, with the optimum spatial distribution of neutron flux (or heat generation) from the core. The link between power control and reactivity control is the core overall temperature

Station output variation following a −0·2 cycles/s step change in the grid frequency (Fig. 3)



coefficient of reactivity. This is positive in the current generation of gas-cooled graphite-moderated metal/magnox reactors for most of their operating life.

During power operation, reactor criticality is distributed by three significant processes:

(*a*) fuel and graphite temperature changes, via the respective temperature coefficients,
(*b*) xenon poison concentration changes,
(*c*) fuel burn-up.

When the overall temperature coefficient of reactivity is positive, the first two processes combine to produce an inherently unstable condition, both in the fundamental flux level, and in the higher harmonics of the radial flux shape. To restore stability, to what is effectively a positive feedback system, requires the addition of an external automatic reactivity varying system in the form of movable neutron absorber. The axial flux shape, however, is predicted to be stable under all operating conditions.

The facility to ensure controlled start-up and shutdown of the reactor requires that large changes in reactivity condition be achieved when desired, by movement of neutron absorbers.

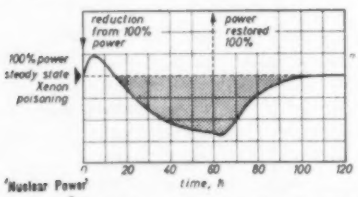
It is a matter of achieving optimum heat generation from the core, and ease of operation, which makes it highly desirable that the axial flux shape should remain substantially unaltered by the presence and movement of neutron absorbers partially inserted in the core. The variation of xenon poison concentration associated with reactor output changes emphasises the need for this design feature in a reactor control system which is to make suitable provision for the possibility of non-base-load operation.

Figure 4 shows qualitatively the sense of reactivity changes experienced as a result of xenon variation following upon a reactor power reduction from 100%, and subsequent restoration. The unshaded area of variation indicates where a compensating release of reactivity is required in the reactor.

The shaded area indicates where coarse control rods must be inserted into the reactor a greater amount than is normal

at full power. The significant feature is the considerable time which must elapse before the coarse control rods are restored to their normal positions in the reactor core.

An automatic control rod system, comprising nine individual control loops is incorporated to provide continuous maintenance of core criticality against fundamental mode and radial/azimuthal mode flux level divergence. Each control loop drives three control rods in a manner to maintain constant to a preset value the average channel gas outlet temperature of the particular area of the core being controlled. The nine control area boundaries take the form of a central circular region surrounded by eight equal sectors. The total reactivity absorption invested in these control rods is kept to a minimum, consistent with effective operation, and their normal axial operating range is from 30% to 60% of full core length.



Typical behaviour of the xenon poison transient following reactor power changes (Fig. 4)

This control rod system closely follows the now accepted pattern of design for such systems in current nuclear reactors of this type.

An integrated control system of coarse and safety rods, manually initiated, meets the functional requirements of reactor start-up, shutdown, and compensation for variation in reactivity due to any changes in the xenon poison concentration from that steady-state value appropriate to full power operation. Long-term reactivity changes following fuel depletion are adjusted by means of variation in the loading of flattening bars.

A feature of the coarse control rod system design is that it is directed towards not causing any significant distortion of the axial flux shape achieved under the full power steady-state condition, when a deficiency in xenon poisoning below that appropriate to the full power steady state condition calls for the presence of more control rods in the core. This is achieved in principle by moving the control rods through the core in small groups. For preserving maximum safety for the plant, considerable care in design is directed towards ensuring that the maximum withdrawal speed cannot be exceeded, and that this shall not cause a reactivity release rate high enough to lead to excessive fuel element temperatures even under the most adverse fault condition.

An additional feature of the coarse rod system is to provide the means of trimming individually the automatic control rods of a local area of the core for axial position.

Each group of control rods is driven by a low frequency electrical supply and design economy requires that the minimum of equipment is used to achieve this.

REACTOR INSTRUMENTATION

The provision of equipment for the measurement, transmission, and presentation of data relating to the essential plant variables has come to be known as instrumentation; in broad outline its function falls into three categories, namely that used for automatic or closed loop control, that for automatic protection action, and that which presents data to an operator for open loop control and protection. It is true to say also that in many cases a particular measured variable will be used for all three functions.

An indication has been given of those variables which contribute to the automatic control of the reactor, it now remains to describe the instrument systems upon which the normal running of the reactor is based and the protection effected.

Fuel element temperature is the dominating controlled variable, although it is not used directly for automatic control; the operator sets the various control demands to achieve the optimum fuel element temperatures. For this purpose he is presented with data derived from the measurement of a significant number of fuel element can temperatures in the plane of maximum temperature. A number of channels are instrumented with thermocouples on most of the elements in a given channel; this affords the operator an axial temperature distribution from which to judge the extent of axial shift of the maximum under conditions other than full power steady state.

Neutron flux measurements is perhaps the next most important variable which is monitored; like fuel element temperature it is not directly introduced into any automatic control system, but is presented to the operator in several ways representing his main information about reactor power output. Measurement is by ion chambers installed in thermal columns located outside the pressure circuit in the manner which is now a well established practice. Several thermal columns are used, spaced approximately uniformly around the periphery of the core, in order to house the necessary instruments in a manner suitable to the overall design layout. The operator is presented with data in the form of linear power in the range 0 to 1250 MWt, high log power, drift power, and period. For low flux conditions, i.e. at start-up or when shut down, indications of low log flux and period are available.

Control rod positions in the core are presented to the operator, as also are total gas mass flow, computed reactor heat output, inlet and outlet gas duct temperatures, and channel gas outlet temperatures for those monitored channels. This completes the more important variables needed for minute to minute operation; there are also measurements of temperatures for graphite, pressure circuit structure, concrete shielding, etc., which provide a longer term survey of the condition of the plant and are suitably processed to afford the operator information upon demand and as a permanent record for statistical purposes.

Protection against unsafe conditions arising in the reactor is achieved automatically by trip shut down, as a result of any departure from the acceptable margin on the essential variables which are monitored.

Reactor trip action results in all the coarse, safety, and automatic control rods being inserted rapidly into the core by cessation of the electrical supply to each control rod motor simultaneously. This is effected by a safety circuit system incorporating three trip guard lines. Thus the rods move into the core under the influence of gravity and are fully inserted after the order of ten seconds, being restrained by inductive braking to achieve an acceptable terminal velocity. It might be said that there is one exception to this, namely the b.c.d. system for detecting failures in the fuel element can; in this case operator action is deemed necessary to assess the action to be taken and the timescale of it. The b.c.d. system proposed is based upon the principle adopted in the Calder Hall reactors and earlier civil programme reactors, where samples of channel gas are presented to precipitation chambers for measurement of activity level.

TABLE 1 *Reactor trip arrangements*

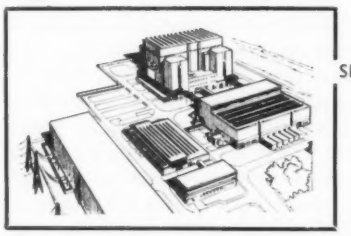
TRIP FUNCTION	TYPE OF INITIATING DEVICE	TYPE OF GUARD LINE COINCIDENCE CIRCUIT	REACTOR OPERATING POWER LEVEL
Low log excess flux	RC/6 ion chamber and period meter	2 out of 3	Source level to 1000W
Low log flux doubling time	RC/6 ion chamber and period meter	2 out of 3	Source level to 1 MW
High log flux doubling time	RC/7 ion chamber and period meter	2 out of 3	1 kW to 1500 MW
High power excess flux	RC/7 ion chamber and amplifier	2 out of 3	50 MW to 1500 MW
Fuel element temperature	Thermocouple and trip amplifier	(2 out of 3)[2] on 9 elements	Independent of power level
Channel outlet gas temperature	Thermocouple and trip amplifier	2 out of 3 for each of 9 sectors	Independent of power level
Circulator speed reduction	Tachometer	(2 out of 3) for (2 out of 4) circuits	Independent of power level
Rate of change of gas pressure	Penumatic resistance capacity system	2 out of 3 for top and bottom gas circuits	Independent power level

Those potentially unsafe reactor conditions, necessitating trip shut down to ensure protection, can only arise following major fault conditions leading to a relative excess of heat generation with respect to heat removal, which results in an increase of fuel element temperatures to those values where the integrity of the materials are jeopardized. Thus two general categories of condition can be set up, namely, uncontrolled increase of heat generation, or failure of the means of heat removal; the former results from a reactivity release, the latter from failure of forced cooling or loss of gas pressure. Thus the essential protection variables are defined, and may be summarized as follows. Ultimate protection is derived from fuel element temperature under all fault conditions, and this is almost invariably designed to be the secondary, or back up trip variable.

For reactivity release type faults the primary trip is derived from flux level or flux doubling time; for loss of cooling, trip will be initiated by two or more circulators reducing speed, or if the cause is loss of gas pressure by negative rate of change of gas pressure. Some details pertaining to the design as tendered are given in Table 1.

In conclusion, it should be stated that while brief details only have been given of reactor instrumentation, it must be appreciated that it is, overall, a most complex system and that part of it associated with reactor protection and plant safety makes demands for the highest integrity of design and incorporated equipment.

Furthermore, it is in this field of design that changes most likely will be made as the contract detail design of the plant progresses and first operational experience from the earlier civil stations becomes available, directed towards improvement in operability and enhanced safety protection.



SIZEWELL NUCLEAR POWER STATION

Close co-operation was necessary to achieve the compact layout

3. *Civil and mechanical design aspects*

by J. D. McKEAN, B.Sc., Chief Reactor Engineer (Development), English Electric Co. Ltd., and N. O. E. LAKIN, B.E., M.A.S.C.E., A.M.I.Struct.E., Chief Civil Engineer, Taylor Woodrow Construction Ltd., at Whetstone.

A DESIGN TEAM'S ABILITY to keep a flexible outlook as long as possible makes a major contribution to developing a successful reactor area layout. The many complex components can then be accommodated in the most economic and convenient manner. A sequential design process in which the thermal performance of the reactor and gas circuits is optimized, the primary circuit designed, the reactor plant and auxiliaries added, and finally, the whole shielded and housed, only results in a costly and unattractive station in which construction and operation are unsatisfactory afterthoughts.

It is easy for plant designers to attempt the most efficient plant layout without reference to civil engineering works. Such a one-sided approach is doomed to failure. Through the nature of the design, the proportion of civil engineering costs are substantially more for a nuclear station than for a conventional one. Therefore, on nuclear power projects there is a definite requirement for ' nuclear power station designers ' rather than mechanical, electrical and civil engineers working separately.

This need for overall thinking can be cultivated by close collaborative work and creating an organization in which specialist engineers are given the opportunity of understanding the problems and incentives existing in other fields of engineering. The successful development of the Sizewell layout was mainly the result of this kind of teamwork.

GUIDING PRINCIPLES

Throughout the design of the reactor area the following objectives, which characterize good reactor design and layout, were kept foremost: (*a*) economic use of materials; (*b*) ease

of construction; (*c*) ease of plant operation, control and maintenance; (*d*) smooth and efficient flow of personnel; (*e*) personnel control; (*f*) manning schedule economy.

Aesthetic considerations are also important and during the later stages of building design must be carefully taken into account.

Of these various objectives, attention to the first and second reflect themselves in the immediate capital cost of the station. The last four mainly influence the operating cost. A good layout represents a balance between the immediate capital cost of the station and the subsequent operational savings achievable. It is of course not possible to give any realistic estimate of the worth of a particular feature which adds to ease of operation, or flexibility in utilization of plant and, because of this difficulty, the factor may well be overlooked at the outset, only assuming its real importance after commissioning.

While the ' optimum ' layout cannot be found by a more or less mechanical process, such as that used to assist in the reactor performance selections, the full range of factors must be kept in mind, and reviewed throughout the period during which the layout is being developed.

The Sizewell layout illustrates the way in which the application of these principles brought about significant departures from previous practice.

PLAN OF ACTION

While success in layout does depend largely on the ability of the design team to retain flexibility of action until quite a late stage, this is of little use unless the engineers responsible for the design of specific items of plant are themselves provided with objectives in their own fields of development. Basically, these objectives are the same as the first three listed in the previous section for the mechanical and civil engineers responsible for reactor area layout.

One of the most important and straightforward ways in which these objectives, and resulting economy, can generally be achieved, is by reducing the number of items of a particular piece of plant required for the station. Apart from reducing overall plant costs, sometimes at the expense of developing components capable of greater output or duty, this method leads to reduction in space required. Another important way by which building volumes can be reduced is by making the gas circuit as compact as possible. Work on the Sizewell major plant and gas circuits was started on these lines at the same time as layout arrangements which might lead to economy were being explored.

DEVELOPMENT OF THE LAYOUT

Gas circuits and reactor orientation

Work on the plant and gas circuit indicated that it would be possible to obtain the required output from each reactor, equivalent to 290 MWe nett sent out, using four boilers and gas circulators. In addition, a gas circuit layout was developed which eliminated the long blower houses associated with separate gas circulators and horizontal shafts. It was immediately appreciated that this compact arrangement could result in a reactor system layout in which the overall dimension across the centre of the reactor from outside wall of the boiler hall on the one side to outside wall of that on the other was less than 250 ft. This was significant as a Goliath type crane is considered essential for the construction of reactor pressure vessels and boilers to achieve the shortest possible construction period, and this dimension could readily be spanned by an existing Goliath crane. This advance permitted the two reactors, coupled to their four gas circuits, to be orientated so that the line joining the centres of the two reactors was parallel with the lines joining the centres of the boiler halls of each reactor, or at right angles to them. With either arrangement, the Goliath crane span did not require to be increased. A serious inflexibility to reactor area layout was now removed and immediately exploited. By turning the reactors, as located in earlier designs, through 90°, it became possible either to develop a single, common irradiated fuel discharge and storage area between the reactors. or to accommodate a single common equipment building between the reactors. Preliminary studies examined all possible arrangements. The designers, however, were not satisfied with the achieving of the one only without the other. Further co-ordinated work was carried out by both the plant designers and the civil engineers and a closely integrated layout emerged which maintained both a single irradiated fuel storage pond and a common equipment building.

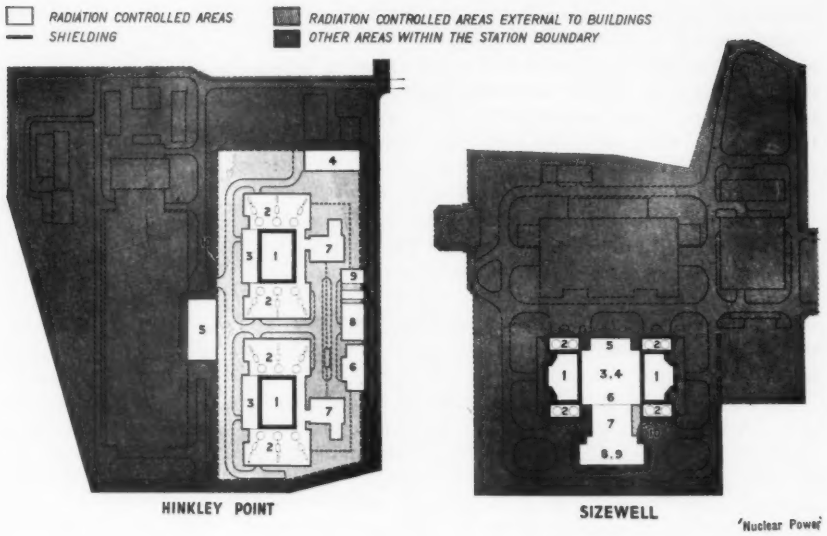
The potentialities of such an arrangement, in which the two reactors with their primary circuits and auxiliary equipment could be housed in a single compact structure, were considerable.

Construction

Construction aspects and difficulties were given early detailed consideration so that the feasibility of the new arrangement could be assured. A great deal of civil engineering work had to be constructed within a comparatively confined area and overall construction programmes would be significantly affected. It would not be possible to provide the same degree of construction access between the two reactors as that possible with previous designs and the common equipment building would require to be completed to suit the plant installation time scale governed by the commissioning date for the first reactor. Ultimately it was decided to depart from previously accepted crane installations and to make use of two specially designed tower cranes, which could cover all parts of the reactors by travelling outside the building lines. It is believed that this will be the first time that these items of plant will be used in this country. These tower cranes and the Goliath crane may be used together with minimum mutual interference and a satisfactory construction programme evolved.

Reactor plant

The fuelling machinery and reactor plant designers were quick to realise the scope which the new reactor orientation permitted. Firstly the numbers of items of plant could be reduced in many cases. Certain fixed standby plant items could be almost halved in number since they could be made available immediately for either reactor. It was also possible to arrange for both reactors to have a common pile cap area since boilers and ducting no longer existed between the reactors. Interchangeability of expensive mobile equipment thus became relatively easy. A further advance was the provision of a common maintenance and decontamination shop within the main building structure below pile cap floor level. Adequate space provision could be made relatively cheaply, thus providing a neat solution to the problem of maintenance and decontamination of massive fuelling machinery. Cranes could be provided which would not only cover the pile cap of each reactor, but which could pass between the two reactors over maintenance and central fuel discharge facilities. All



Comparison of the Hinkley Point and Sizewell reactor area layouts (Fig. 1)

1 reactor; 2 boilers and circulators; 3 reactor equipment; 4 fuel store; 5 change rooms & control room; 6 decontamination; 7 pond; 8 radioactive effluent treatment plant; 9 laundry; 10 boundary of radiation controlled area

this resulted in a very flexible arrangement of reactor operation with economy of manpower as well as plant.

Station control

The general common building arrangement presented another very important possibility. This concerned the station control centre and arrangements for supervision and maintenance of certain plant. It had been specified that boilers and ducts should be adequately shielded so that radiation levels outside the reactor building are below permissible levels for personnel unconnected with reactors. In the Sizewell design, this meant that provided adequate precautions were taken to prevent the spread of radioactive contamination, access round the full perimeter of the common reactor building could be unrestricted, except for one very small section adjacent to the maintenance shop entrance at the back of the building. This permitted economy in roadways, the space they occupy and consideration to be given to reducing the distance between turbine hall and reactors, with consequent savings in interconnecting services. It was also possible to consider the location of the station control centre in the reactor building itself. Provided separate ventilating arrangements were made and shielding checked so that entry to the control room could be made without passing through change rooms, a fourfold advantage would occur:

(*a*) The extensive cabling between control room and reactors would be reduced in quantity and complexity.
(*b*) The central control room equipment would be at the same earth potential as the reactor equipment, giving economy and security.
(*c*) Essential control cabling would be given security against external hazard.
(*d*) The station control room would be in its rightful place in a nuclear power project.

Plant access

With this new building and shielding concept, it was also possible to consider other areas within the combined reactor building which would benefit if they were accessible without needing to pass through a change room. The diesel generator standby plant, which is intimately associated with the safety of the reactors, and the reactor auxiliary transformers and switchgear could be housed inside the reactor building so that they could be manned and maintained by personnel who would not normally pass through a change room. Similar treatment could be given to the vertically mounted gas circulator motors and auxiliaries, and also to the boiler circulating pumps. A facility of this kind removes a restriction on the station operator, permitting him to use his personnel in the most economic manner.

The common pile cap floor and general overhead crane coverage arrangement lends itself to more extensive use of the top face of the reactors and the avoidance of penetrations in the reactor side shield walls. The plant designers appreciated the difficulty and complexity associated with side wall penetrations, not only in the arrangements which have to be made for handling weighty plant in the horizontal plane, but also in the shielding excrescences which accompany them. Two instances of advance in this direction for Sizewell are the burst cartridge detection stand-pipes with valves, and the arrangements for insertion and withdrawal of ion chambers. This equipment is brought out at pile cap level with consequent economy and where routine operations and maintenance can be carried out under conditions of strict control. The more extensive use of the pile cap floor area has also given considerable scope to the plant designer in utilizing existing equipment for more than the purpose for which it was originally intended.

Shielding

Within the reactor building, the shielding layout and dimensions are influenced by civil engineering considerations. The designers responsible for the gas circuit and plant are well aware of the conditions most acceptable to the civil engineer and deliberately select arrangements which can lead to clean walls and avoidance of overhang or cantilevered shielding. The thickness of the shielding is determined by the properties of the concrete. The thicknesses used are generally related to the composition and density of the cheapest available concrete from local materials, although of course extra cost of transporting denser aggregate may be justified by reduction in the quantity required. The layout of the shielding allows for easy shuttering. Plane faces in duodecagonal form around the pressure vessel are considered slightly cheaper than circular shapes. The arrangement of the

shielding is planned to ensure that its load bearing potential is used wherever possible. Heavy columns above the pile cap level are, therefore, spaced so as to bear on masses of radiation shielding. The walls of the shielding are maintained as uniformly as possible to permit the repetitive use of formwork. In some areas where additional shielding is required, involving a local thickening of walls, precast blockwork, which is installed late in the construction programme, is adopted.

The pile cap crane is a heavy structure when carrying its full load and every effort is made to transfer this load to the foundations through the masses of shielding concrete. The crane spans and end clearances were tailored to suit the shielding layout, and the shielding arrangement of a double skin envelope was influenced by the need to obtain an economic structure to support the crane.

The main shielding for Sizewell is, therefore, a duodecagonal well with 6 ft thick walls surrounded by a rectangular box with 4 ft 6 in thick walls. The two thicknesses combine to give the protection required. The space between the two shields is used to house the shield and pressure vessel cooling air ducts, and provides storage for active solid waste materials. The supplementary shielding around the main gas ducts is connected to the outer rectangular walls of the main shield, which are quite independent of the inner duodecagonal shield. This offers an advantage in construction as, if necessary, the inner shield can be constructed independently and quickly to suit the installation of the pressure vessel sections.

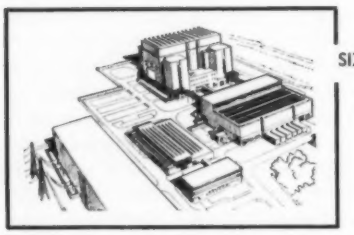
Equipment building

The common equipment building is constructed in reinforced concrete. This enables the facilities already available for the large scale placing of concrete to be used to the full. The reactor plant designers accepted the slight inflexibility resulting from the use of reinforced concrete in order to obtain the greater overall economy, and plant design and manufacturing programmes are modified to suit.

GENERAL

Apart from all the detail developments outlined above which were applied to Sizewell, serious efforts were made towards reducing the number of auxiliary buildings which have surrounded the reactor buildings of previous designs. Significant advances were made in this direction.

Figure 1 compares the Hinkley Point reactor area with that for Sizewell. It shows the new orientations of reactors and boilers; the very significant reduction in building area; the losing of the reactor restricted area fence; the condensing of the ancillary buildings; the convenient placing of the station control room; and the elimination of much of the roadway. All these factors contributed to the advance achieved in the Sizewell design.



SIZEWELL NUCLEAR POWER STATION

Boiler shells will be made in alloy steel and each will contain two complete bypass systems

4. Gas circuits and boilers

by T. B. WEBB, B.Sc., M.I.Mech.E., M.I.Chem.E., Manager, Atomic Energy Department, Babcock & Wilcox Ltd.

THE DESIGN OF THE Sizewell gas circuit and boilers, shown in outline in Fig. 1, is in the main a straightforward development of the pattern set at Hinkley Point; most of the improvements following directly or indirectly from the increased gas pressure (264 instead of 185 lbf/in²g) made possible by the greater strength of the reactor vessel and from the incorporation of the gas circulators in the boiler shells.

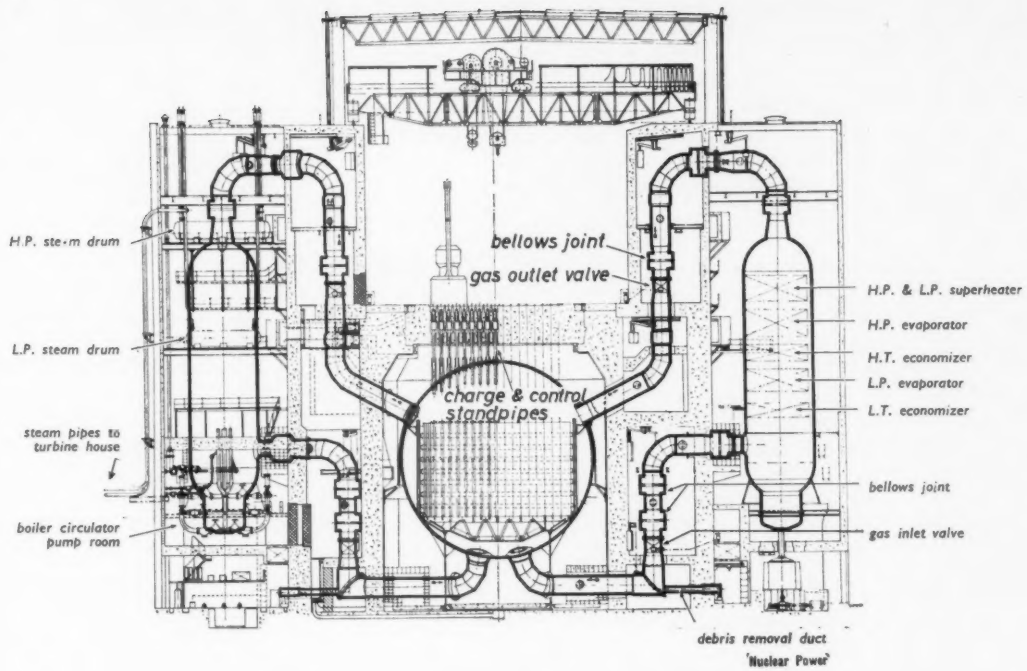
REACTOR VESSELS

These are 63 ft 6 in diameter, in silicon-killed mild steel of a uniform thickness of 4⅛ in, and nowhere has there been any incentive to depart from the design solutions adopted at Hinkley Point and Trawsfynydd. The thickness of 4⅛ in does not represent any sophisticated optimization; early in the project it was considered that the maximum thickness likely to be readily accepted in the light of the limitations at that time in site non-destructive testing technique was 4 in, and the design of the complete system proceeded on this basis. Subsequently, the authorities introduced the new requirement that the sum of the pressure membrane stress and the stress due to self weight, where this was uniform through the plate section, should not exceed the Code design stress. At the same time it was conceded that a weld efficiency factor of 0·95, as specified by BS1500, was more appropriate than the figure of 0·90 formerly adopted for reactor vessels. The combined effect of these two changes, one positive and one negative, brought the thickness to 4⅛ in.

The material chosen was similar to that at Hinkley Point, except that the carbon content was reduced and the manganese increased in order to make it easier to obtain the stipulated Charpy test value of 20 ft lb at —10°C. The analysis is as follows:

Carbon	0·16% max.
Manganese	1·0–1·4%
Silicon	0·15–0·30%
Phosphorus	0·04% max
Sulphur	0·04% max

In the quest for high impact values at low temperatures it should be remembered that some of the means by which



Section through one of the reactor buildings showing two of the main gas circuits (Fig. 1)

these qualities are obtained may introduce other more realistic troubles in the form of plate unsoundness; but it is considered that the material chosen represents a reasonable compromise.

The design of the duct openings and charge nozzles is the same as at Hinkley Point. There is full compensation for the openings calculated in accordance with BS1500, although strain gauge readings obtained during the pressure tests at Hinkley Point have now shown that the radial stress in the region of the openings is greater than the circumferential, indicating that the amount of reinforcement required by the Code is greater than the optimum. At Hinkley Point all these components were forgings, but at Sizewell they will be machined from cylinders made by electro-slag welding of bent billets and plates. This process, which is now acceptable, is more economical.

The weight of the core, about 3000 tons, is, as at Hinkley Point, transmitted to the foundations through a cylindrical skirt joined to the reactor vessel by a forged cruciform section of 34 ft diameter. This construction, found satisfactory at Hinkley Point and Trawsfynydd, has been again adopted because it is considered to give the minimum increase of stress in the reactor vessel wall, such stress being fully calculable, and because all joints are butt welds which can be fully radiographed. A contribution towards the stress system in this region is the temperature gradient in the lower skirt near the vessel; this is minimized by the use of aluminium conducting plates enclosed in an insulated pocket. The proportions of these were determined in full scale tests in the Research Department.

Laminated stainless steel insulation as first applied at Hinkley Point will be attached to the inside surface of the upper part of the vessel; this, in conjunction with the external cooling air system, will ensure that the vessel wall does not exceed 650°F, thereby permitting the maximum Code design stress to be employed.

A difference from Hinkley Point is that the reactor inlet ducts enter the vessel within the skirt; this has been made possible by a reduction from six circuits to four (see Fig. 2).

There are few changes in the manufacturing method for the Sizewell vessels. The plates are pressed to radius and machine welded by submerged arc in pairs at the Works, then set up into courses to check their accuracy; all the welds associated with the duct openings are made in the Works and stress relieved there before shipment. At site the plates are hand welded with Babcock electrodes in three prefabrication shops into complete courses. These will be lifted into the biological shield by the Goliath crane which is now in process of being dismantled at Hinkley Point to be reerected at Sizewell. At Hinkley Point, the sphere was completed before cutting the holes for welding in the charge tube nozzles. First at Bradwell, and later at Trawsfynydd, a different procedure was employed; the whole of the top cap of the vessel, including the nozzles, was prefabricated on the ground and then lifted into the biological shield and this procedure will be adopted at Sizewell. Although the maintenance of positional tolerances on the charge nozzles is thus made more difficult, a saving of four to five months in this critical part of the construction programme is achieved. When complete, the vessels will be stress relieved by internal radiant heaters and pressure tested pneumatically as has become standard practice.

The core support grid in the vessel is similar to that at Hinkley Point; it is a rectangular arrangement of ten openwork trusses designed to occupy the minimum space and to afford the minimum restriction to gas flow. By comparison with Hinkley Point, the details are somewhat simpler, making use of both tubular and rectangular sections. Each structure

is made up of five sections fabricated and stress relieved in the Works and then welded together on site before lifting into the reactor vessel.

DUCTING

Largely owing to the higher reactor gas pressure, it has been possible to handle almost the same mass flow as at Hinkley Point in four gas circuits instead of six without appreciable penalty in blower power.

The duct runs, while generally resembling those in ot er nuclear stations, are much simpler than at Hinkley Point because the blowers are now accommodated in the base of the heat exchanger vessels, a layout which was first adopted at Hunterston. In addition, the inlet connexions to the reactor vessel are made at a low level inside the support skirt, resulting in one of the cleanest layouts yet produced. Further simplification results from the by-pass circuit, provided originally to enable the blower to be run during start-up in a small closed circuit containing only the low temperature economizer to absorb the heat generated, being contained entirely within the heat exchanger shell. Thus, at Hinkley Point there are 144 hinged bellows units and in the Sizewell tender design only 48. The hinged bellows units will contain convolutions of chrome-molybdenum steel, 5 ft 6 in in diameter, mounted in restraints of the Hinkley Point pattern containing simple pin joints. Alternative forms of bellows restraint were examined but no reason could be found to justify a departure from the original design.

For Hinkley Point, a simple but effective design of right-angle corner piece containing cascade blades was developed(*1*). For Sizewell, an analysis of the manufacturing and erecting costs indicated that a form of ' lobster-back ' bend made up of 3, 4 or 5 short cylinders would be more economical without attracting any pressure loss penalty; these have been adopted except at one position in the lower duct run where there is insufficient space and where the Hinkley Point type of cascade corner provides better facilities for debris removal arrangements.

The main circuit butterfly valves will be 5 ft 6 in diameter of Hopkinsons manufacture, and similar to Hinkley Point.

During the contract engineering stage, a more detailed examination of the various operating conditions and the resulting expansion stresses in the ducting and the reactor and heat exchanger vessels was undertaken. This showed that it is possible to dispense with the hinged bellows units in the duct run between the reactor outlet and the heat exchanger inlet by making two additional changes; (*a*) to strengthen the connexion to the heat exchanger vessel, and (*b*) to replace the lobster-back bends with smooth bends fabricated by pressing half segments of a toroid and welding together along the outer and inner extremities, so ensuring that the stress concentration factor in the bends is limited. This latter step is necessary in order to accommodate the Von Karman stresses which are set up in the sides of the bends due to departure from a circular cross section when they deflect to take up the thermal expansion. It is therefore likely that the plant as built will contain this modification, which has the advantage of slight reduction of blower power requirement together with elimination of some maintenance work during the life of the station.

BOILERS

The boilers, Fig. 3, bear a superficial resemblance to those at Hinkley Point; the type of heating surface and its disposition are similar but there are, in fact, some major changes. In particular, the boiler shell is made of alloy steel and now accommodates the vertically mounted gas circulator and two complete by-pass systems with valves. Table 1 shows some of the essential dimensions and quantities in relation to those for Hinkley Point.

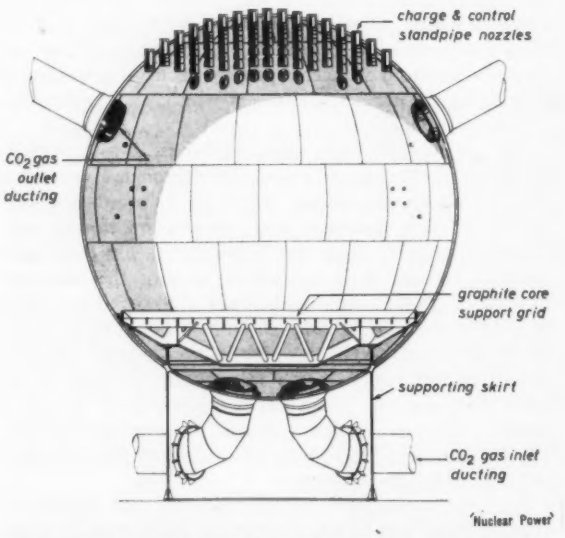
Making allowance for the parallel portion of the shell being 13 ft 6 in longer than would be necessary if the blower were separately mounted, the rate of heat transmission is about 32,500 Btu/h ft³ of shell volume, over 20% higher than the maximum figure previously published (*2*). This has been achieved by a heating surface similar to that at Hinkley Point, except that the studs are now $\frac{3}{4}$ in high instead of 1 in, but this enables the tubes to be pitched closer together so that, in spite of the shorter studs, the total heating surface per cu. ft of tube bank is slightly greater than at Hinkley Point. The shortening of the studs, leading to higher fin efficiency, is of course a logical development in view of the higher gas pressure and greater mass flow. The selected proportions of surface are the result of extensive experimentation in atmospheric and pressurized test rigs (*3*).

The studded heating surface was chosen rather than any of the alternative forms for the following reasons:

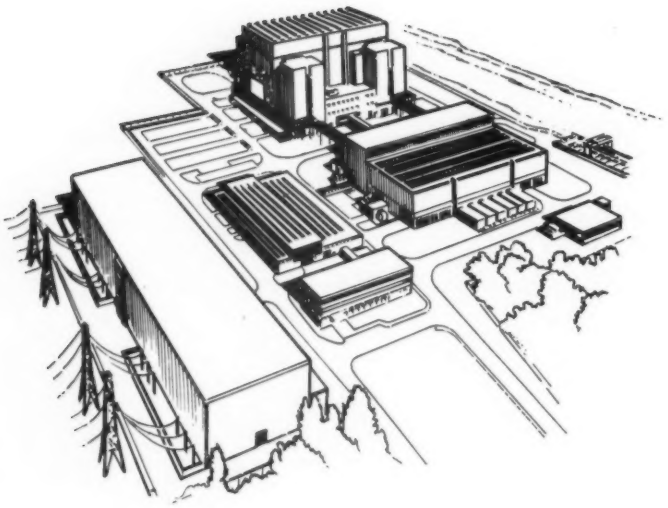
(*a*) The Company already has extensive satisfactory experience and the necessary manufacturing equipment is installed and working.

(*b*) It is simple to arrange for the studding to be interrupted leaving short lengths of bare tube free from studs. This enables supports to be fitted easily and also permits long lengths of tube to be bent after studding, thereby economizing on the number of butt welded return bends necessary.

(*c*) Experimental work has shown that this type of surface is less likely than some others to give rise to gas vibrations. The risk of this phenomenon is always present in heat exchangers operating with high mass flows across banks of tubes and there is no way, other than a full scale test, of being certain that it will not occur.



Sectional view of the 63 ft 6 in dia. reactor pressure vessel which will be fabricated from 4½ in thick 28/32 u.t.s. silicon-killed carbon/manganese steel plate (Fig. 2)



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Sizewell Principal Data

Performance

Number of reactors	2
Nett sent out electrical	289·16 MW/reactor
Nett efficiency	30·51%
Heat transferred to gas by reactor	947·7 MW/reactor
Heat transferred to steam in boiler	963·5 MW/reactor
Gross generated output	318·8 MW/reactor
Gross cycle efficiency (gross output /heat transferred to steam)	33·09%
Circulator power at generator terminals	21·94 MW/reactor
Auxiliary load (other than main gas circulators)	7·70 MW/reactor

Core and Fuel

Weight of uranium	320·8 tonnes/reactor
Canning	Magnox
Weight of moderator	2237 tonnes/reactor
Core size (not including reflector)	45 ft × 26 ft
Flattened radius	15 ft
Lattice pitch, square	8 in
Graphite channel diameter	3·85 in
Fuel rod diameter	1·1 in
Fuel element length	41 in
Number of elements per channel	7
Maximum can temperature	453·7°C
Average centre channel rating	288·4 kW
Nominal maximum uranium temperature (at channel irradiation of 1500 MWd/T)	575·5°C
Mean heat generation/max heat generation (radial)	0·8675
Mean heat generation/max heat generation (axial)	0·7178
Mean fuel rating	2·954 MW(th)/T
Max fuel rating	4·744 MW(th)/T
Mean fuel life	3120 MWd/tonne
Pressure vessel diameter	63 ft 6 in
Pressure vessel thickness	$4\frac{1}{8}$ in

Boilers and Turbines

Number of boilers	8
	22 ft 6 in

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Nuclear Power
REACTOR MATERIALS INSTRUMENTATION PROCESSES IRRADIATION

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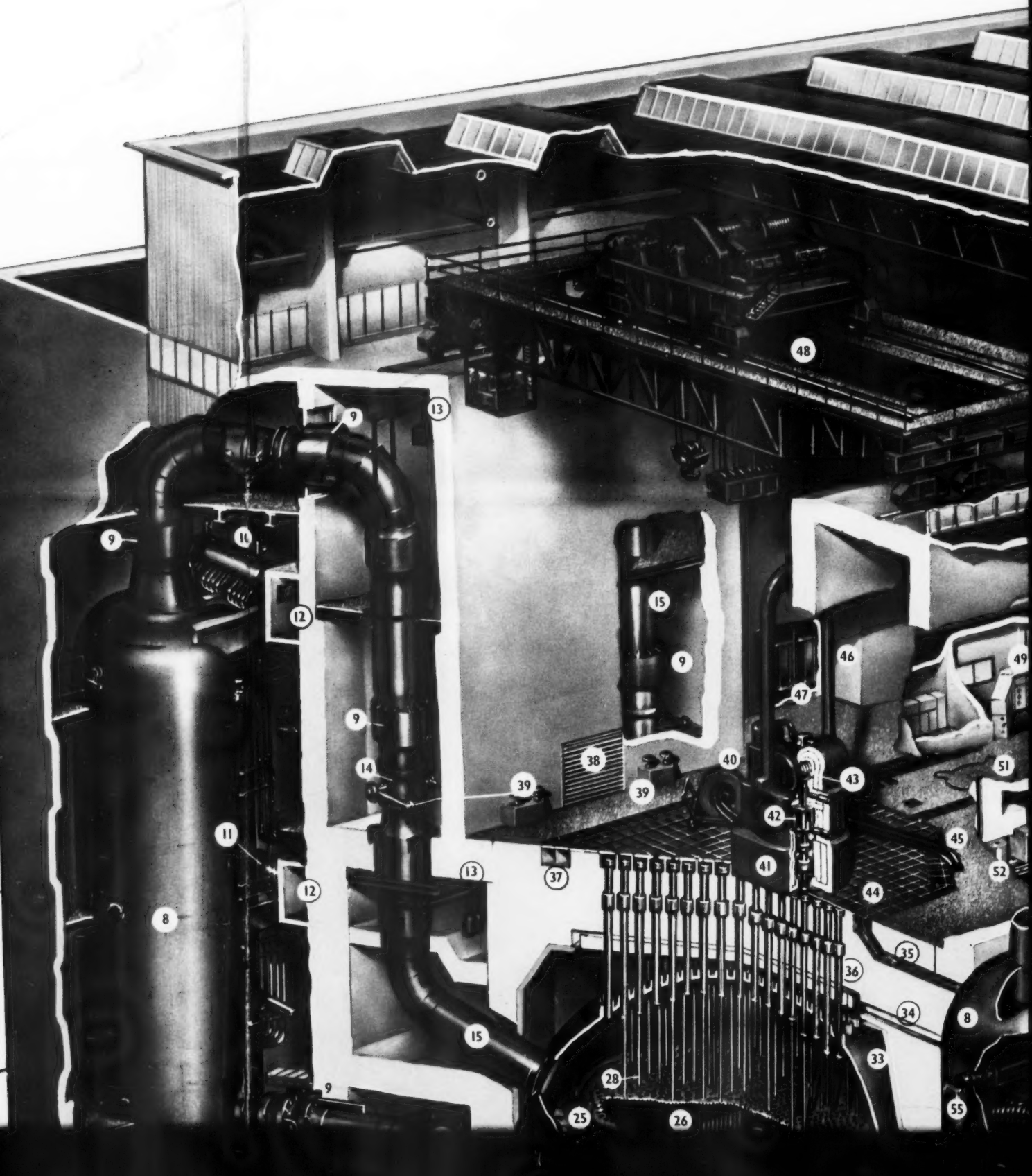
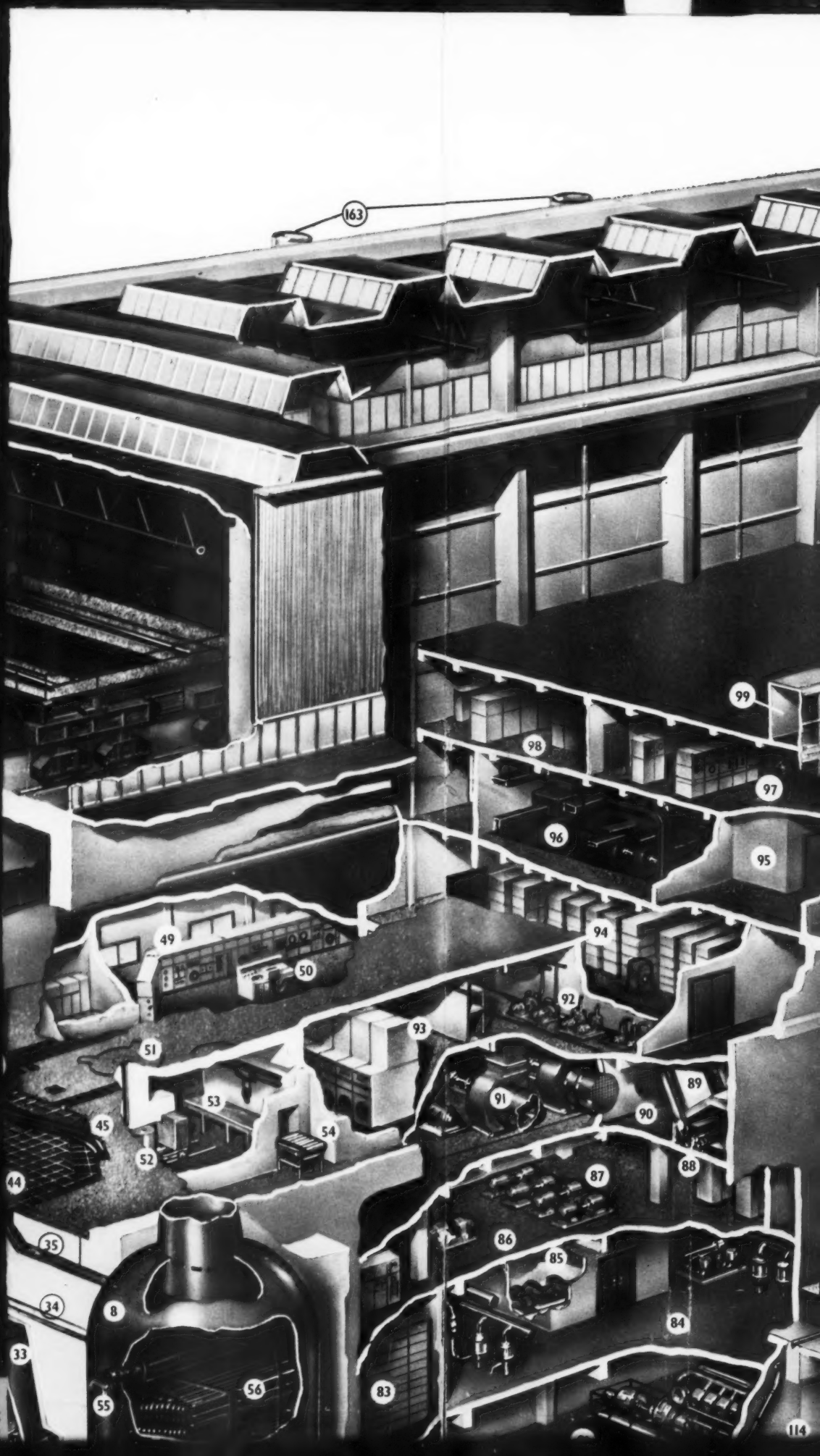
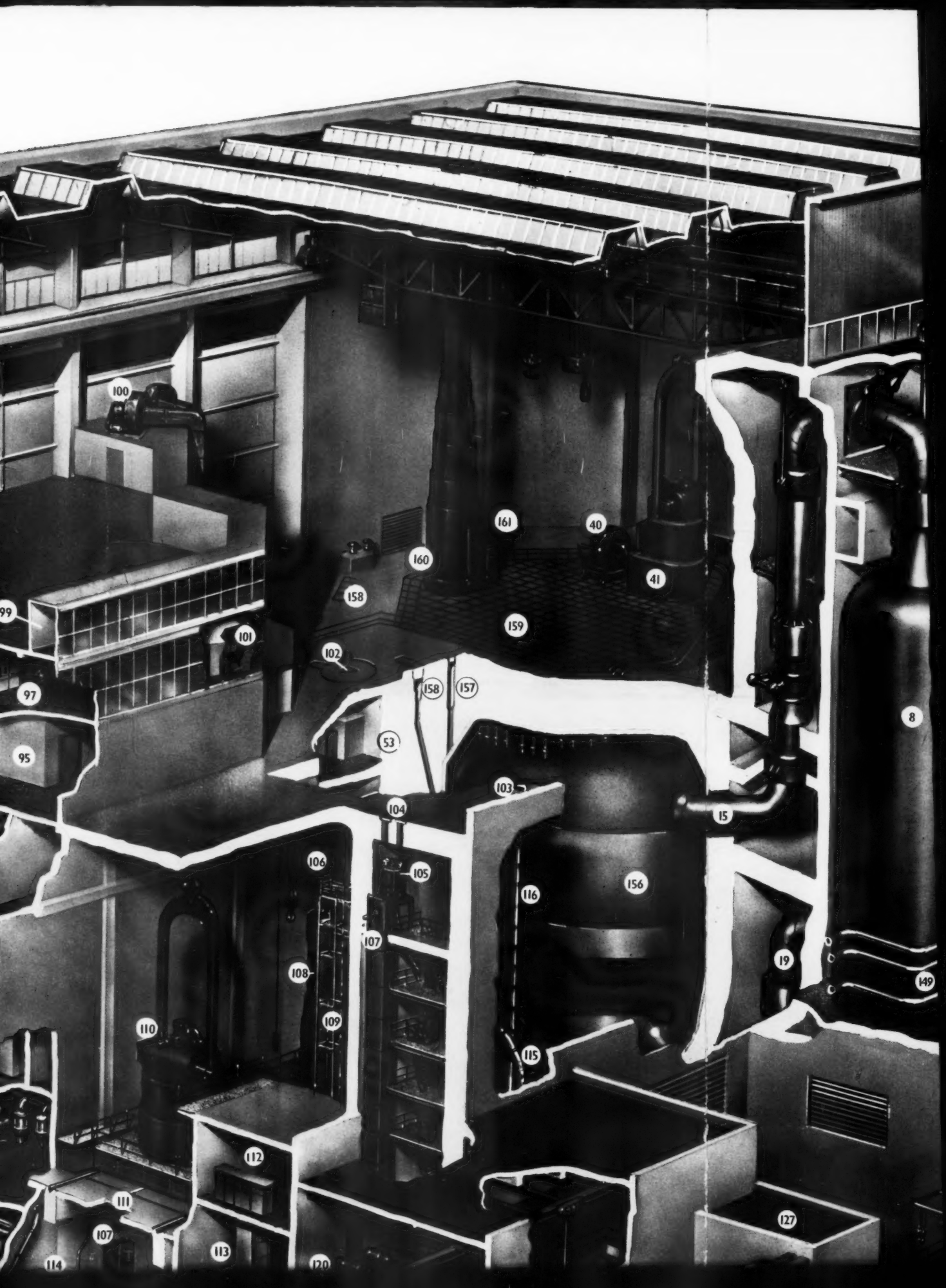




ber of boilers	8
r diameter	22 ft
el length	62 ft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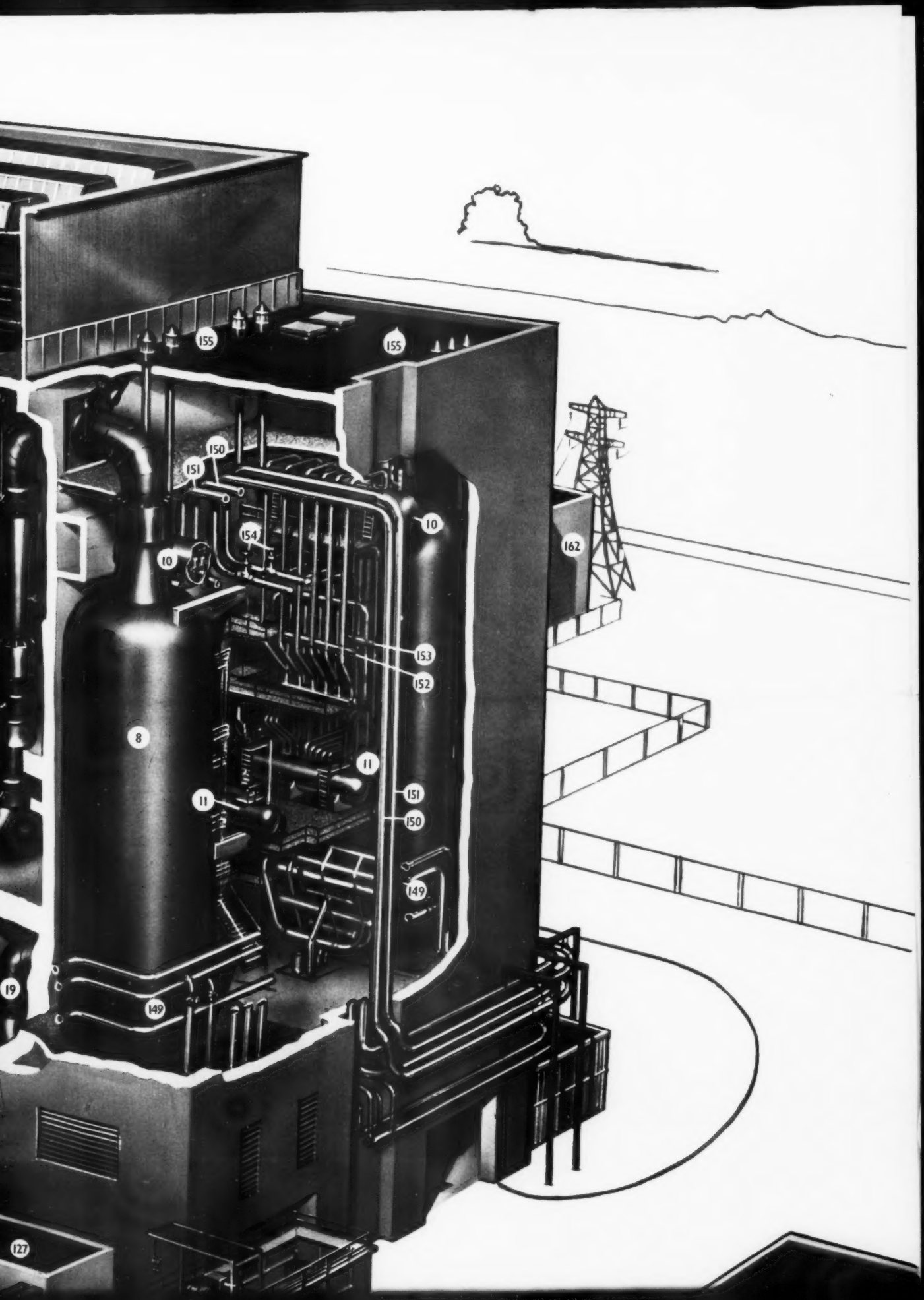
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generation (axial)	0·7178
Mean fuel rating	2·954 MW(th)/T
Max fuel rating	4·744 MW(th)/T
Mean fuel life	3120 MWd/tonne
Pressure vessel diameter	63 ft 6 in
Pressure vessel thickness	$4\frac{1}{8}$ in

Boilers and Turbines

Number of boilers	8
Boiler diameter	22 ft 6 in
Parallel length	62 ft
Total length	91 ft 6 in
HP drum pressure	720 lbf/in²a
HP superheater outlet temperature	398·8°C
LP drum pressure	321·5 lbf/in²a
LP superheater outlet temperature	400·4°C
HP steam pressure	661·9 lbf/in²a
HP steam temperature	393·9°C
LP steam pressure	291·2 lbf/in²a
LP steam temperature	396·8°C
Vacuum	29 in Hg
Total steam flow/reactor	2·834 lb/h × 10^6
Ratio of HP steam flow/total steam flow	0·7544
Final feed temperature	120·6°C
Turbine exhaust pressure	0·539 lbf/in²a
Number of main turbines	2
Output of each main turbine	324·75 MW

Circulators

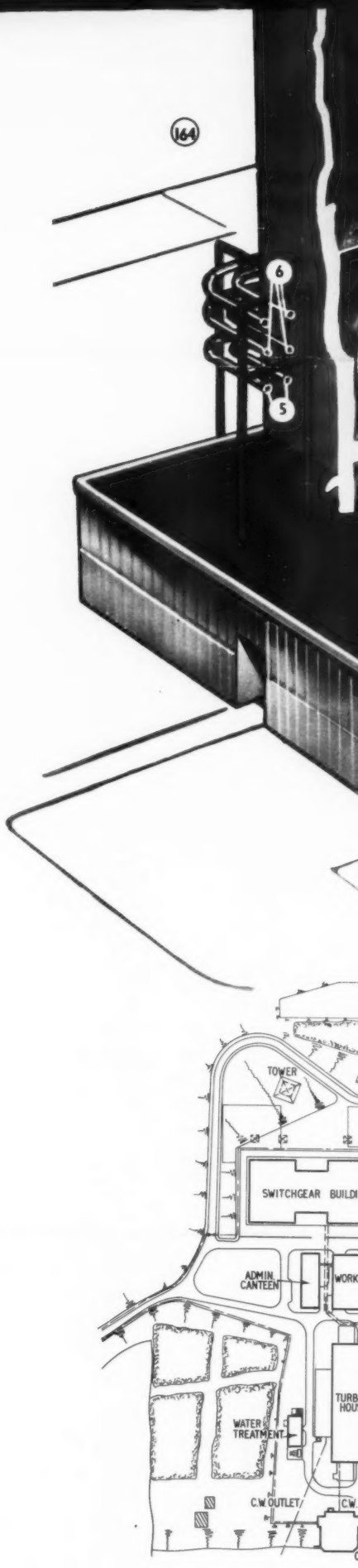
Number of circulators	8
Type of circulator	Vertical, single stage axial with variable stagger inlet guide vanes
Drive	Vertical squirrel cage induction type motor

Gas Circuit

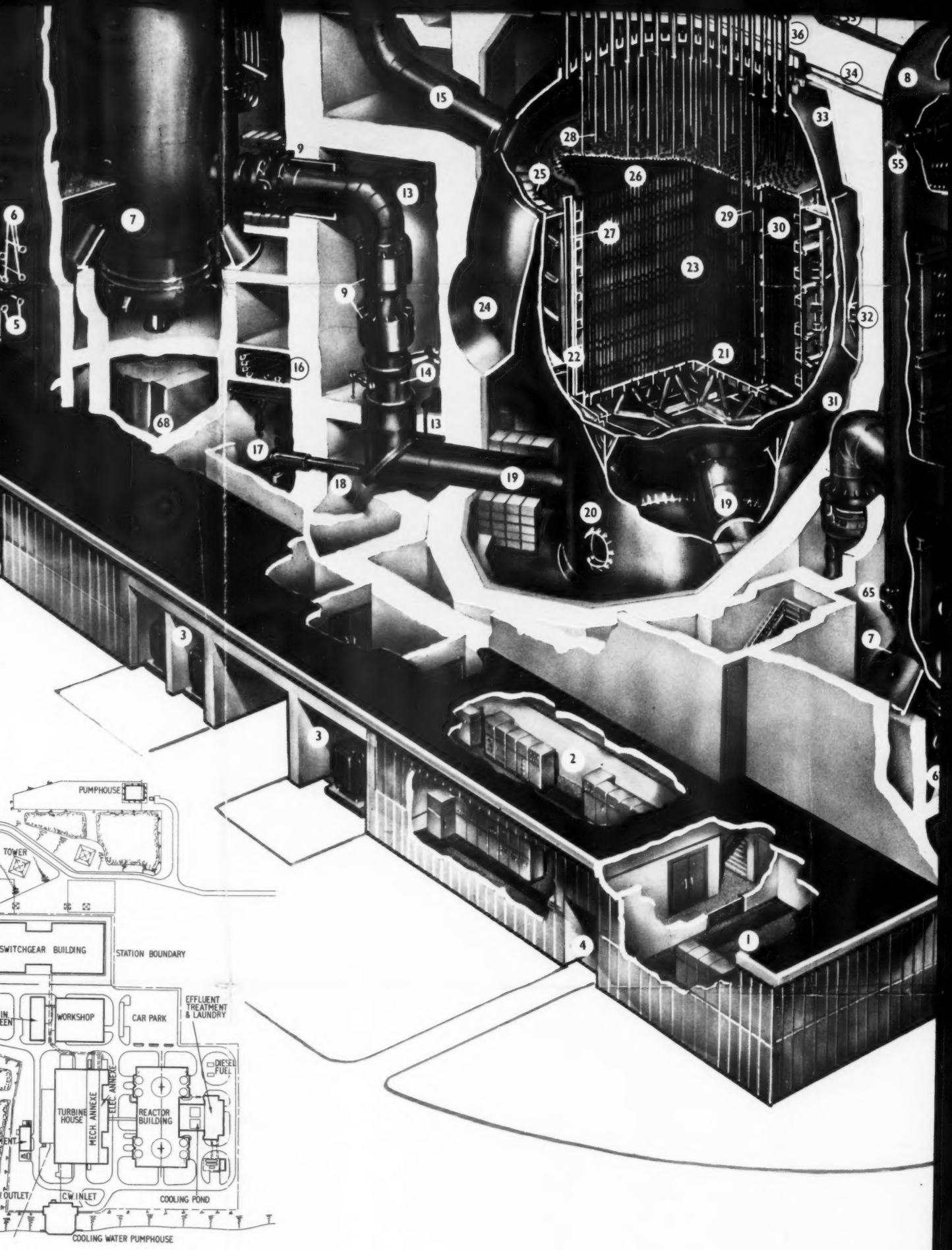
Reactor gas inlet pressure	278·8 lbf/in²a
Reactor gas inlet temperature	214·1°C
Reactor gas outlet temperature	409·9°C
Total gas flow/reactor	9854 lb/s
Total gas circuit pressure drop	11·09 lbf/in²
Pressure drop across reactor	5·32 lbf/in²
Pressure drop across fuel elements	4·30 lbf/in²
Centre channel mass flow at channel inlet	3·010 lb/s
Filtering and drying bypass flow, % of reactor gas flow	0·5

Civil Engineering Data

Height of reactor building	192 ft
Length of reactor building	352 ft
Mean thickness of concrete main shield	5 ft 6 in
Mean thickness of concrete supplementary shield	5 ft
Distance across flats of main shield	72 ft 3 in
Height of concrete main shield	96 ft
Thickness of pile cap	11 ft 9 in
Foundation of reactor building	Reinforced concrete raft 228 ft × 106 ft × 8 ft thick
Turbine hall overall dimensions	Approx 385 ft × 160 ft × 90 ft high
Pumphouse dimensions	125 ft wide × 133 ft long
Circulating water flow	27 × 10^6 gal/h



1 Gas circulator instrument and control room
2 Gas circulator instrument
13 Counter-weight supports
14 Isolating valves
29 Control rod
30 Fuel elements

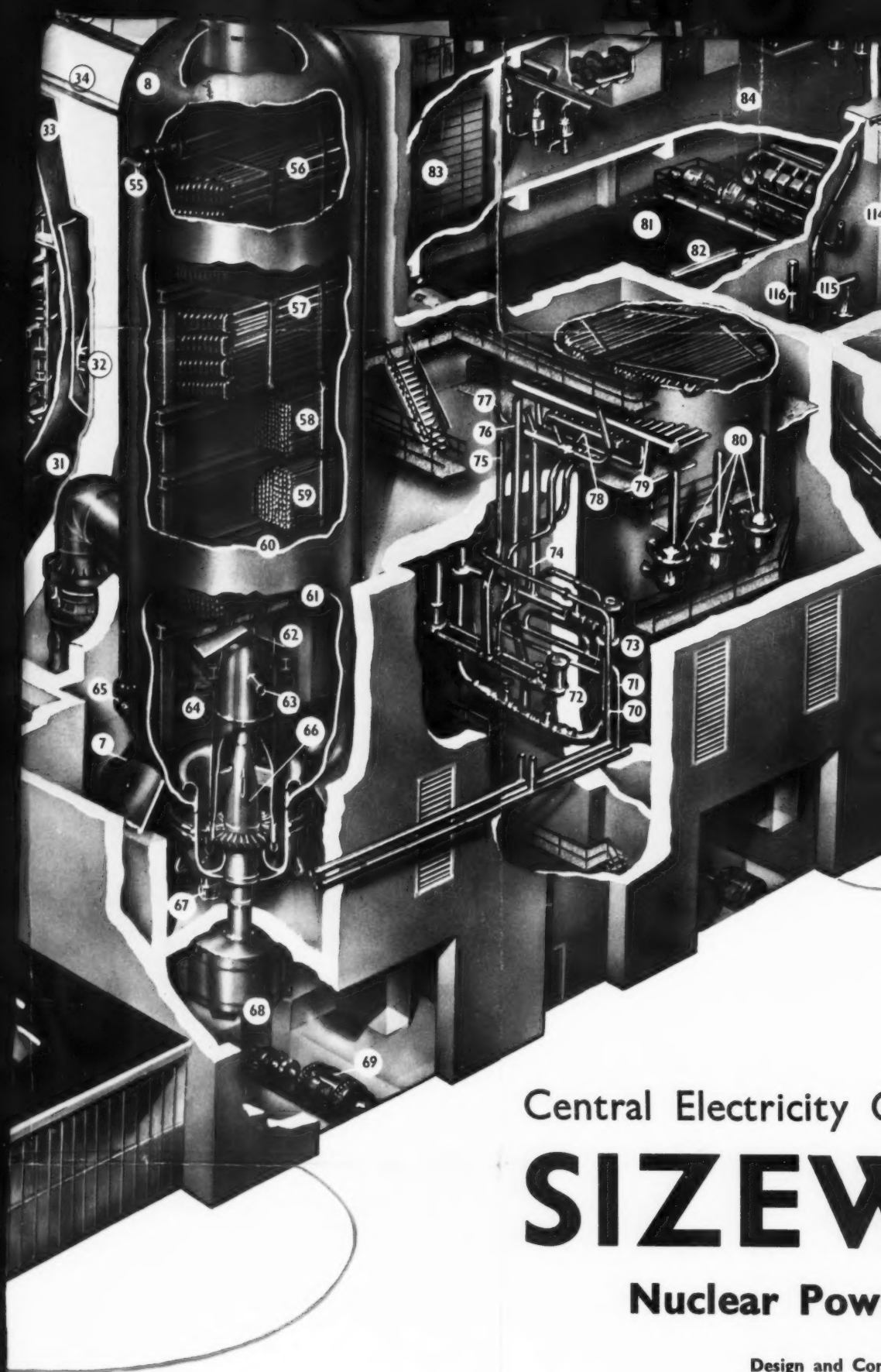


43 Fuel element grabhead hoist drum

56 Mixed H.P. and L.P. superheater

drive motor

82 Diesel exhaust and silenc



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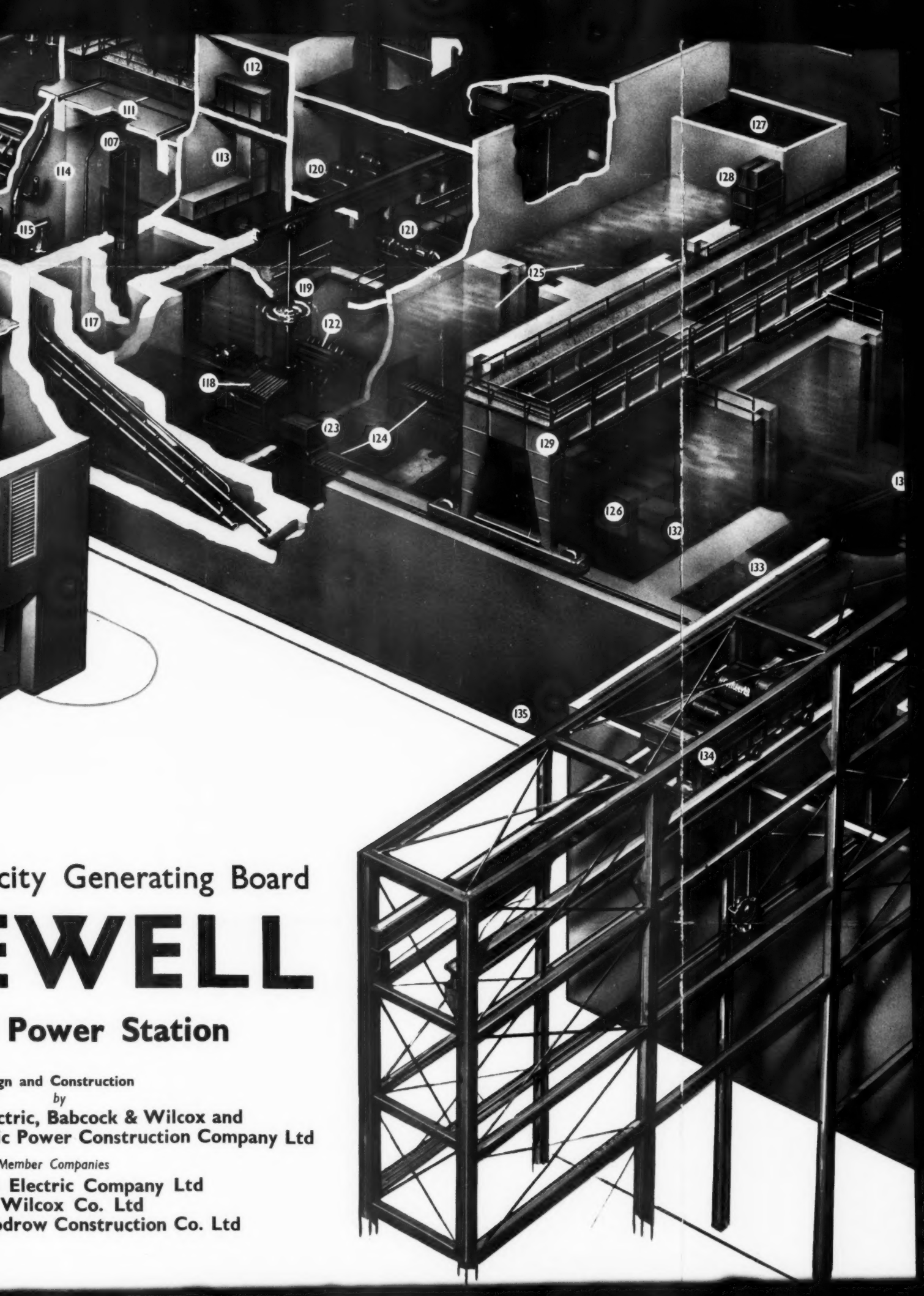

city Generating Board

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Power Station

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by
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c Power Construction Company Ltd

Member Companies
Electric Company Ltd
Wilcox Co. Ltd
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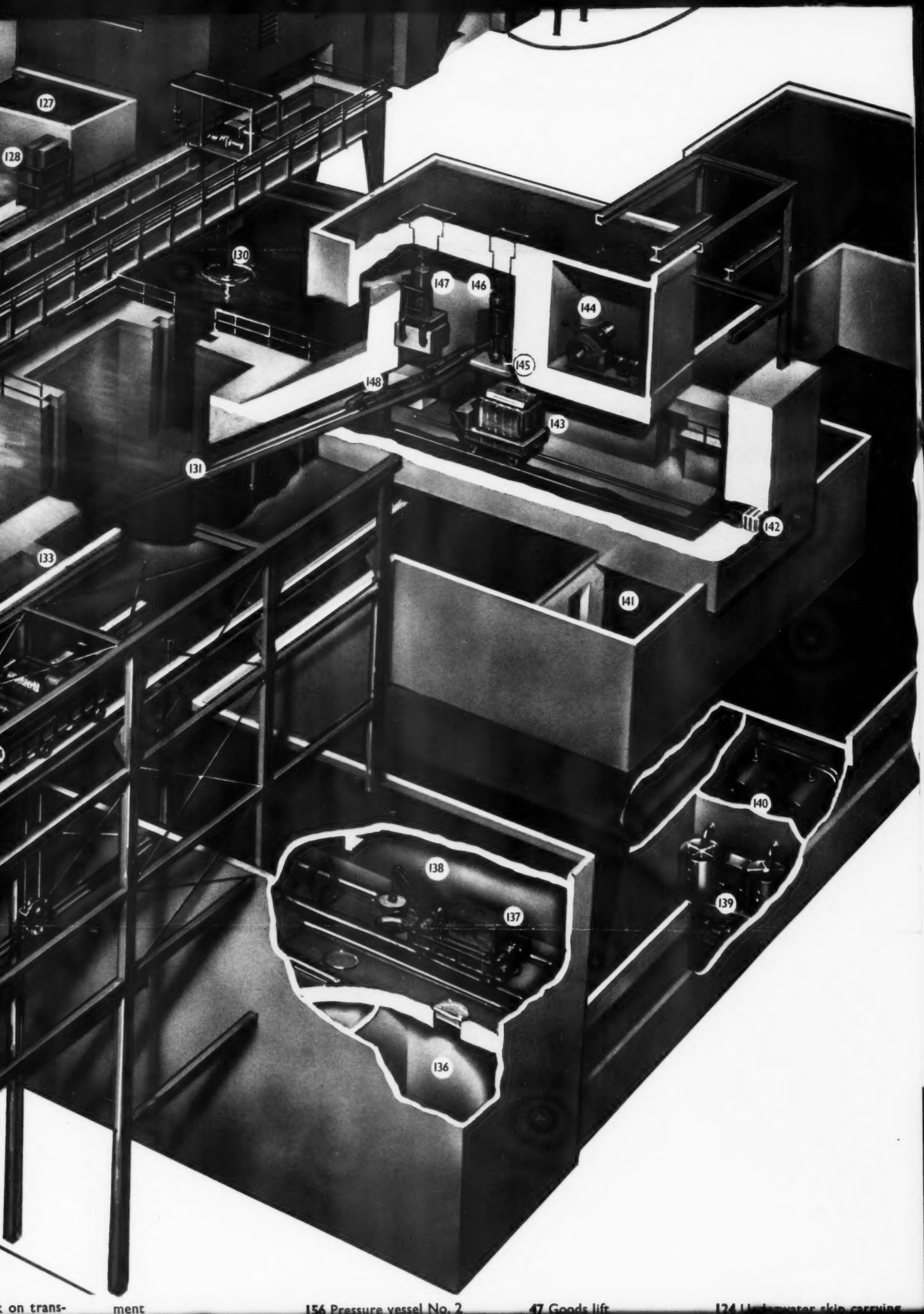
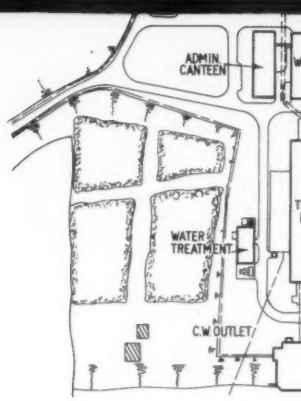


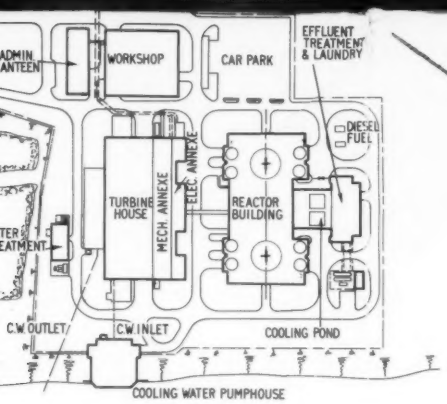
k on trans- ment

156 Pressure vessel No. 2 47 Goods lift 124 Underwater skip carrying

Mean thickness of concrete main shield	5 ft 6 in
Mean thickness of concrete supplementary shield	5 ft
Distance across flats of main shield	72 ft 3 in
Height of concrete main shield	96 ft
Thickness of pile cap	11 ft 9 in
Foundation of reactor building	Reinforced concrete raft 228 ft × 106 ft × 8 ft thick
Turbine hall overall dimensions	Approx 385 ft × 160 ft × 90 ft high
Pumphouse dimensions	125 ft wide × 133 ft long
Circulating water flow	27 × 10^6 gal/h



1 Gas circulator instrument and control room
2 Gas circulator instrument room
3 Auxiliary transformers
4 Emergency exit
5 L.P. and H.P. feed water to boilers
6 L.P. and H.P. steam to turbines
7 Boiler support skirt
8 Boiler
9 Gas duct bellows joint
10 H.P. steam drum
11 L.P. steam drum
12 Shielded galleries
13 Counter-weight supports
14 Isolating valves
15 Gas outlet ducts
16 Cable duct
17 Debris removal corridor
18 Debris removal duct
19 Gas inlet ducts
20 Pressure vessel support skirt
21 Moderator support grid
22 Gas seal
23 Graphite moderator
24 Cooling air cowl
25 Gas baffle
26 Charge pans
27 Core restraining structure
28 Control rod guide tubes
29 Control rod
30 Fuel elements
31 Side wall cooling pass
32 Thermal column
33 Pressure vessel No. 1
34 Cooling air passage to standpipes
35 Cooling air passage to pile cap
36 Pressure vessel standpipes
37 Service trench
38 Demountable wall for gas duct valve removal
39 Isolating valve drives
40 Pile cap service trolley
41 Fuelling machine
42 Fuelling machine magazine



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43 Fuel element grabhead hoist drum
44 No. 1 reactor pile cap
45 Services to fuelling machine
46 Fuelling machine lifting beam
47 Goods lift
48 Pile cap crane
49 Central control room
50 Control engineers desk
51 Fuel loading facility, reactor No. 1
52 Fuel transit magazine
53 Fuel preparation rooms
54 Conveyor for fuel elements
55 Reactor inlet gas, boiler by-pass control valve
56 Mixed H.P. and L.P. superheater
57 H.P. boiler banks
58 High temperature H.P. economizer
59 L.P. boiler
60 Mixed low temperature H.P. & L.P. economizer
61 Exit from boiler by-pass
62 Hot gas deflector plates
63 Filter by-pass connexion
64 Reactor gas flow control valve
65 Reactor gas flow control valve drive shaft
66 Gas circulator
67 Variable stagger guide vane drive motor
68 Main circulator motor
69 Auxiliary circulator motor
70 H.P. water feed
71 L.P. water feed
72 L.P. circulating pump
73 H.P. circulating pump
74 L.P. boiler inlet
75 L.P. downcomer
76 H.P. downcomer
77 H.P. boiler inlet
78 L.P. economizer inlet box
79 H.P. economizer inlet box
80 Gas pressure relief valve filters
81 Standby diesel generator sets (4)
82 Diesel exhaust and silencer
83 Main fuel store
84 CO_2 ancillary equipment room
85 Vacuum pumps
86 Control rod electrical supply
87 Reactor safety circuit motor generator sets
88 Used shield cooling filter spool removal trolley
89 Shield cooling filters
90 Outlet ducts from filters
91 Shield cooling fans
92 Frequency convertors and compressors for b.c.d. equipment
93 Burst cartridge detection

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Nuclear Power

Design and Constru

by

The English Electric, Babco
Taylor Woodrow Atomic Power Co

Member Companie

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Babcock & Wilcox Co.
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equipment room
94 Sub-fuel store
95 Assistant engineer's office
96 Ventilation plant
97 Pile cap supervision room
98 Pile cap switchgear
99 Vistors viewing gallery
100 Pile cap ventilation fans
101 Fuelling and servicing machines control desk
102 Fuel loading facility, reactor No. 2
103 Emergency fuel discharge point
104 Fuel discharge shaft
105 Bottling machine for fuel elements
106 Maintenance workshop
107 Conveyor for irradiated fuel elements
108 Reactor servicing machine in maintenance workshops
109 Servicing machine maintenance structure
110 Fuelling machine in maintence workshop
111 Access hatch to decontamination shop
112 Switchgear for ma
shop pond servi
113 Instrument de
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114 Decontamination
115 Emergency disch
bottling machine
116 Emergency fuel
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117 Shielded disposal
118 Fuel element s
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119 Fuel element
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in pond reception bay
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120 Pond water circulating pumps
121 Emergency discharge braking jet pump
122 Fuel element guide vane removal machine
123 Fuel element skip on underwater conveyor
124 Underwater skip carrying conveyor
125 Pond fuel element reception bays
126 Fuel element storage skips
127 Emergency fuel element discharge tonging room
128 Penstocks in storage position
129 Cooling pond crane
130 Cooling pond crane mast
131 Fuel element skip hoist
132 Pond storage compartment
133 Liquid effluent final monitoring and delay tanks
134 Gantry for irradiated fuel transport flask conveyance
135 Cables and supplies trench
136 Fuel element guide vane shielded store
137 Guide vane flask on transporter
138 Carriage operating room
139 Dilution mixing tanks
140 Acid and caustic plant
141 Irradiated fuel transport flask decontamination room
142 Cable reeling drum
143 Irradiated fuel transport flask on conveyor carriage
144 Skip hoist winch room
145 Irradiated fuel transport flask lid
146 Pneumatic lid lifting equipment
147 Pneumatic skip equipment with position
148 Skip hoist carriage
149 Ancillary gas circu work
150 L.P. steam from bo
151 H.P. steam from bo
152 H.P. steam main
153 L.P. steam main
154 H.P. and L.P. boi valves
155 Relief valve dischar

flask on trans- 147
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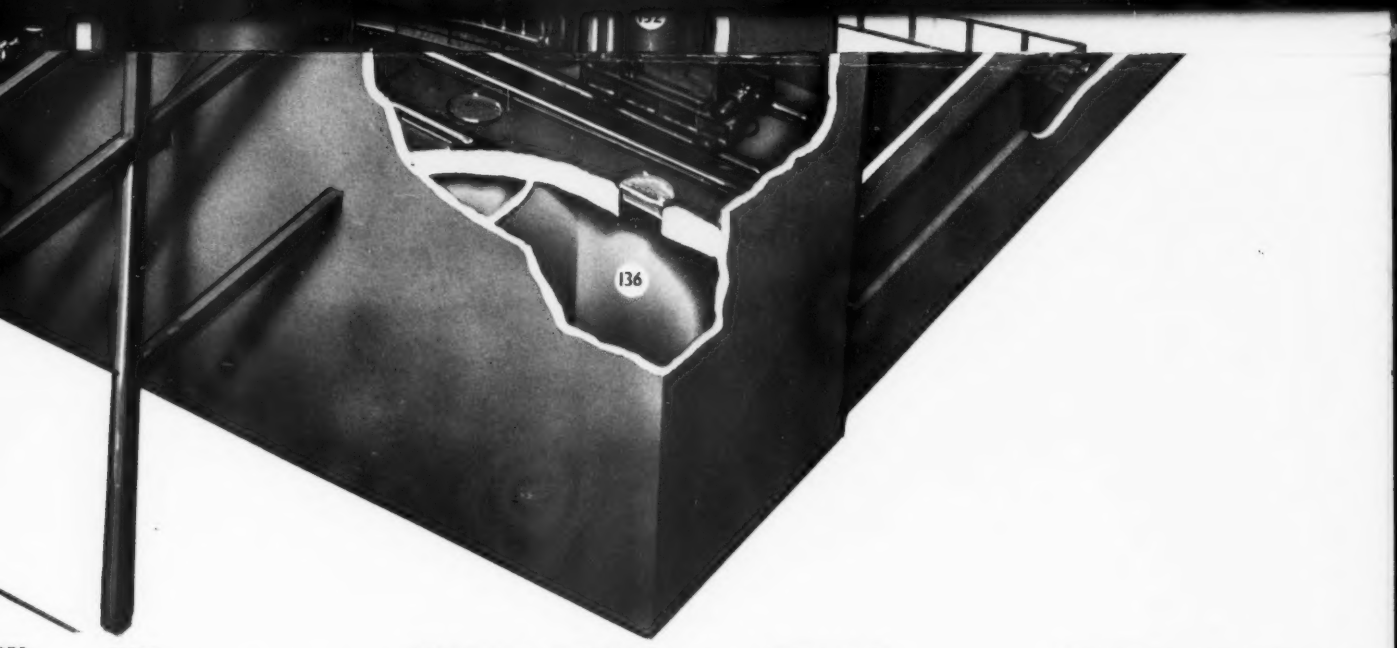
d lifting equip- 155



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147 Pneumatic skip lifting equipment with skip in position
148 Skip hoist carriage
149 Ancillary gas circuit pipework
150 L.P. steam from boilers
151 H.P. steam from boilers
152 H.P. steam main
153 L.P. steam main
154 H.P. and L.P. boiler stop valves
155 Relief valve discharge pipes
156 Pressure vessel No. 2
157 Pressure vessel inspection periscope viewing position
158 Ion chamber passage
159 No. 2 reactor pile cap
160 Reactor servicing machine
161 Emergency control console
162 Station switchgear building
163 Exhaust stacks
164 Turbine hall

PATH OF FUEL ELEMENTS

Clean

83 Main fuel store
47 Goods lift
94 Sub-fuel store
53 Fuel preparation rooms
102 & 51 Fuel loading facility
41 Fuelling machine

Irradiated

104 Fuel discharge shaft
105 Bottling machine for fuel elements
107 Conveyor for irradiated fuel elements
118 Element segregating tray in pond reception bay
124 Underwater skip carrying conveyor
126 Fuel element storage skips
131 Fuel element skip hoist
147 Pneumatic skip lifting equipment with skip in position
143 Irradiated fuel transport flask on conveyor carriage
141 Irradiated fuel transport flask decontamination room
134 Gantry for irradiated fuel transport flask conveyance

(*d*) There appeared to be no economic advantage in making a change.

Owing to the close pitching of the tubes, there are now more elements in a bank. In order to reduce the number of penetrations through the shell, thereby facilitating erection, the tubes in the superheating, evaporating and high temperature economizer sections are arranged in groups of three; each is connected through forged trifurcation pieces to one 2 in tube passing through a thermal sleeve in the shell wall.

The heating surface will be cleaned by shot-blasting in the Works and then, after weathering in transit and at site, acid-cleaned immediately before erection.

The arrangement of banks is similar to that at Hinkley Point, except that the low pressure evaporating section has now been accommodated in one bank and the two superheaters, instead of being in series, are in parallel. Forced circulation on the La Mont principle by Hayward Tyler glandless submersible pumps has been used for the evaporating sections. For these boilers there is little to choose between forced and natural circulation; the former gives greater freedom of arrangement of drums, piping and heating surface, whereas the latter saves the power consumption and the cost of the circulating pumps.

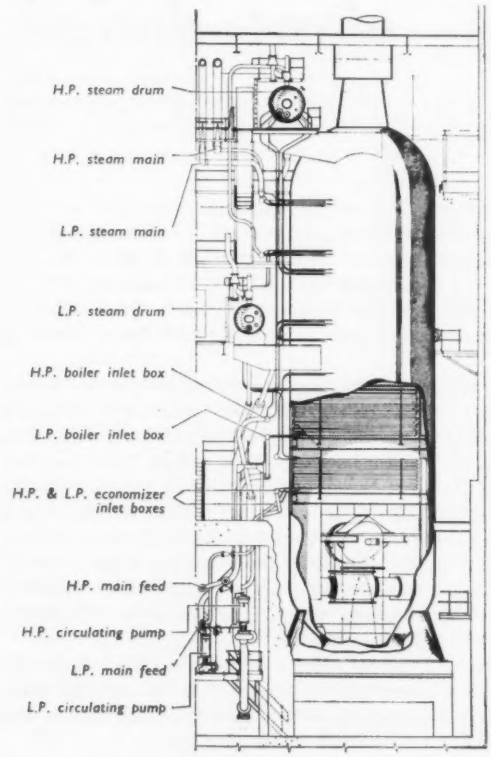
A feature of this design is the incorporation of a by-pass to all the heating surface in the boiler in order to provide a means for controlling the inlet temperature to the reactor. This is accommodated in a rectangular space 19 ft 0 in by 1 ft 6 in, passing down the centre of the unit and is controlled by a 22 in diameter cylindrical ported valve at the top.

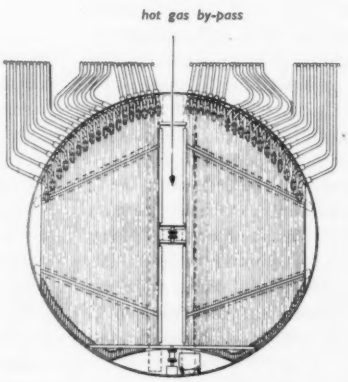
The vertical gas circulator is mounted in a short 12 ft diameter cylindrical extension to the lower dome of the shell and discharges via a cascaded right-angle corner through the side of the shell near the bottom. By means of internal baffles and a 36 in diameter cylindrical ported valve, arrangements are made to enable the gas from the blower outlet to be short-circuited through the low temperature economizer back to the blower inlet. This facility is available at Hinkley Point by means of an external by-pass circuit to enable the blowers to be run up when commissioning a boiler, but at Sizewell it will also be used in conjunction with variable stagger of the blower stator blades to provide reactor gas mass flow control in operation.

If the boiler shells had been made of mild steel their thickness would have been such that they would have been too heavy for the 400-ton Goliath crane to handle them. Advantage was therefore taken of the development which had already been proceeding to establish a satisfactory higher tensile alloy steel for use in site welded reactor vessels and these shells are being made of a manganese-chrome-molybdenum-vanadium steel with a minimum u.t.s. of 34 tonf/in². This material retains its strength at moderately elevated tempera-

TABLE I *Comparison of Sizewell and Hinkley Point boilers*

	DIAMETER, ft	in	PARALLEL LENGTH, ft	in	HEAT FLOW, MW	MASS FLOW, lb/s	STEAM TO GAS TEMPERATURE APPROACH, °F	GAS PRESSURE, lbf/in²	GAS PRESSURE LOSS, lbf/in²
Hinkley Point	21	6	65	3	164	1720	20	180	1·6
Sizewell	22	6	62	0	241	2463	18	257	2·1





Side elevation and section through a boiler, there are four per reactor each 91 ft 6 in high, 22 ft 6 in dia. fabricated from 2¼ in steel plate (Fig. 3)

'Nuclear Power'

tures which enables the shells to be made of a uniform thickness of 2¼ in. The analysis is as follows:

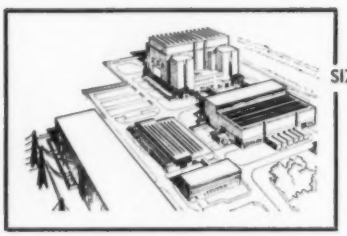
Carbon	0·10–0·15%
Silicon	0·30% max
Manganese	1·20–1·50%
Sulphur	0·04% max
Phosphorus	0·04% max
Chrome	0·45–0·70%
Molybdenum	0·25–0·30%
Vanadium	0·07–0·12%

This is based on steel with which there is many years' experience in the Company's Works in fabricating large boiler drums up to 5½ in thick.

Manufacturing procedures will be much the same as for the mild steel vessels at Hinkley Point, except that the plate will be delivered to the Works in the normalized condition. Cold rolling will be employed for forming the cylindrical part of the shell and hot pressing for the hemispherical ends. Welding in the Works will be by automatic submerged arc, and on site by hand with Babcock electrodes using a preheat temperature, as in the case of mild steel, of 100°C. By employing sea transport from the Works on the Clyde to Lowestoft Harbour, it is possible to ship the cylindrical section in five complete rings. This enables all pressure part welding, including the thermal sleeves and larger connexions, to be completed and stress relieved in the Works, with the exception of seven circumferential welds which will be made at site and stress relieved individually by induction heating as at Hinkley Point. Erection of the shells to their plinths will be by the Goliath crane and subsequent tubing carried out under clean conditions through the blower opening at the base of the vessel.

References

1. Mackenzie, A. C., and Beattie, I. M., I.Mech.E., Symposium on Pressure Vessels, Jan., 1961.
2. *Nuclear Power*, 1961, April, 91.
3. Worley, N. G., and Ross, W., 'Heat transfer and pressure loss characteristics of cross-flow tubular arrangements with studded surfaces,' I.Mech.E. Symposium on the Use of Secondary Surfaces for Heat Transfer with Clean Gases, Nov., 1960



SIZEWELL NUCLEAR POWER STATION

The blades on the last rows of the 324·75 MW turbine will be the longest in the world

5. Conventional plant design

by C. BOTTRELL, A.M.I.E.E., Chief Power Station Engineer, Atomic Power Division, and J. CALDWELL, B.Sc., A.R.T.C., Whit.Sch., M.I.Mech.E., Chief Engineer, Steam Turbine Division, English Electric Co. Ltd.

IN THE EVOLUTION of the general plant arrangement careful consideration was given to operating and civil engineering costs and the economic use of building volume. The basement level was determined from a comparison of capitalized pumping costs with civil engineering costs. The plant arrangement is shown on the plan and cross section illustrations, Figs. 1 and 2. The two turbo-generators are arranged longitudinally with steam end to steam end, the re-heaters being located between the sets. The mechanical annexe to the main turbo-generator house will contain the feed heating plant, main and emergency feed pumps, emergency condensate, reactor pond make-up and fire protection plant, together with the associated steam, condensate and feed pipework. The two high-level deaerators will also be installed in the annexe.

The Turbine House, which will be steel-framed, will have two 95-ton capacity cranes arranged to operate in tandem with a lifting beam to raise the heaviest load—the generator stator. For other lifts the cranes will be operated independently. An auxiliary lift of 25 tons capacity is incorporated in each crane.

Two loading bays, one at each end of the Turbine House, will give adequate space for turbo-generator and plant maintenance.

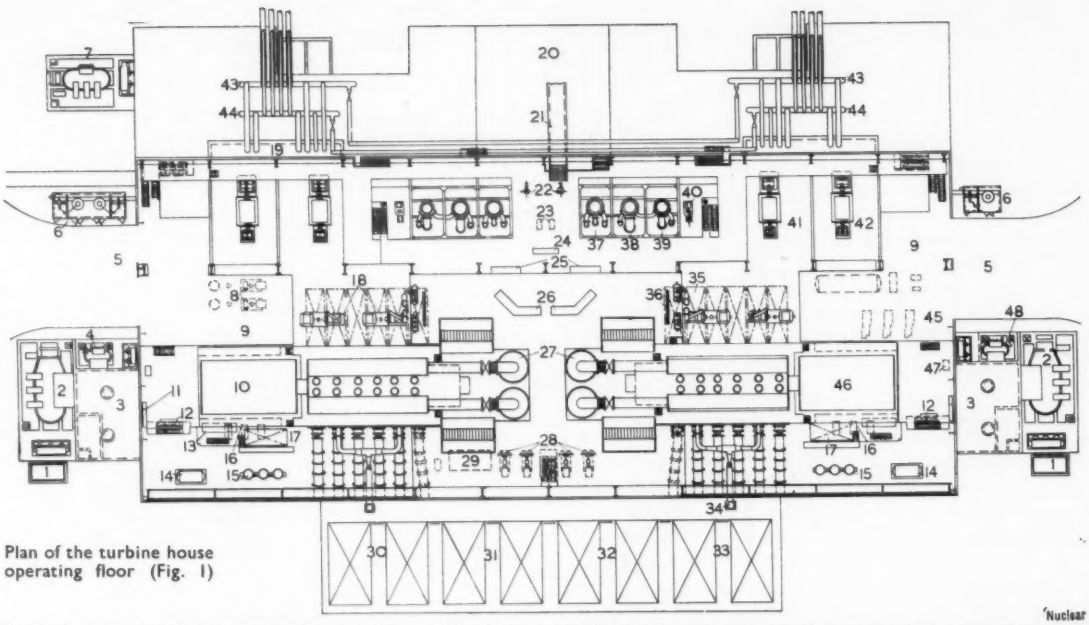
For economy of cable runs and to make neat connexion arrangements, the main generator and unit transformer for each unit will be located at each end of the Turbine House.

An electrical annexe on the north side of the mechanical annexe will contain the 11 kV and 3·3 kV switchgear for the station auxiliaries; in the central portion there will be a locker room, ablutions, etc. for Turbine House operating staff.

The main steam pipes between the boilers and the Turbine House will be carried on two trestle bridges and will end in two pairs of headers, one high pressure and one low pressure, on the electrical annexe roof. There will be interconnecting pipework between the headers capable of carrying the full load requirements to each set so that if either a main set or a reactor is lost, some advantage could be taken by ranging up the steam system. Normally the interconnecting pipework would be closed and each main set would be run unitized with the corresponding reactor. The two trestle bridges will also carry the feed water pipes.

The boiler make-up water will be derived from bore holes and the raw water will be treated in a de-ionization plant which will discharge to the condensers and to the six low level reserve tanks outside the Turbine House.

Under conditions of total failure of electricity supply from the main sets or the grid, the separate 'essential' supply system using diesel generators will provide power for



Plan of the turbine house operating floor (Fig. 1)

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1 break tank; 2 generator transformer; 3 generator switch plant room; 4 unit transformer No. 2; 5 entrance; 6 neutral earthing compound; 7 station transformer; 8 station air compressors; 9 loading bay; 10 No. 2 turbo-generator set; 11 hydrogen auxiliaries and oil pump control panels; 12 oil purifier; 13 rectifier cubicle; 14 oil seal unit; 15 oil coolers; 16 oil pumps; 17 oil tanks; 18 condensate extraction pumps; 19 pipe duct; 20 electrical annexe; 21 personnel bridge; 22 emergency condensate pumps; 23 pond make-up pumps; 24 fire protection plant switchboard; 25 pump control and tank indicator panel; 26 turbine gauge board, supervisory panel and vacuum boards; 27 two-stage re-heaters; 28 G.S.W. pumps and strainers; 29 oil storage tank and pump; 30, 31, 32 reserve feed water tanks; 33 fire tanks; 34 atmospheric exhaust pipe; 35 tube withdrawal area; 36 air ejectors and valve stand; 37 No. 2 L.P. heater; 38 No. 1 L.P. heater; 39 drains cooler; 40 emergency boiler feed pumps; 41 main boiler; 42 feed pumps; 43 H.P. steam header; 44 L.P. steam header; 45 fire protection equipment under loading bay; 46 No. 1 turbo-generator set; 47 stator C.W. header tank; 48 unit transformer No. 1

the motor driven emergency boiler feed pumps which will pump the water from the reserve tanks to the boilers to ensure adequate cooling for the shut down reactor.

CIRCULATOR DRIVE AND AUXILIARY SUPPLIES

The main gas circulators for the reactors are to operate at constant speed; the gas mass flow is controlled from the control room by varying the opening of the inlet guide vanes of the circulators and also by the operation of a gas by-pass valve mounted within the boiler shell. This system of control is very efficient under the whole range of station load from low load at high system frequency to maximum load at low system frequency. The inter-relation of variable opening with gas by-pass also ensures that the circulator is always operating on a stable portion of its characteristic. The main circulators are single stage axial flow type, each circulator being mounted vertically within the boiler shell and arranged for upward flow.

The drive motor will be of the squirrel cage induction type arranged for direct-on starting. The coupling for the circulator will be a gear type coupling at the top and there will be a pony motor coupled via right-angled gear box at the bottom end.

The main motors are rated at 8700 hp each and for direct-on starting require to be of very rigid and robust construction. They are totally enclosed with a closed-air circuit for ventilation powered by an axial flow fan at the end of the rotor. Heat from the motors will be dissipated by water coolers.

Special handling equipment is to be provided for the circulators and main motors within the circulator motor house. This equipment will be used for the initial erection of the plant and for subsequent maintenance purposes.

The main motors' supplies will be at 11 kV from unit boards supplied from unit transformers. This voltage was considered to be the most practicable for motors of this size. From a study of the economics for the supplies of the other motors over 150 hp, it was decided that a 3·3 kV auxiliary supply system was justified in addition to the 11 kV supplies. For motors and other supplies below 150 hp these are fed at the standard 415 V. The station has, therefore, a three voltage auxiliary power supply system for the main supplies, apart from the separate 'essential' supply system for safety and emergency purposes.

In considering the design of the electrical system and switchgear rating, the following conditions had to be met:

(i) system stability under fault conditions
(ii) good voltage regulation under running conditions
(iii) satisfactory voltage drop under starting conditions
(iv) simple operation.

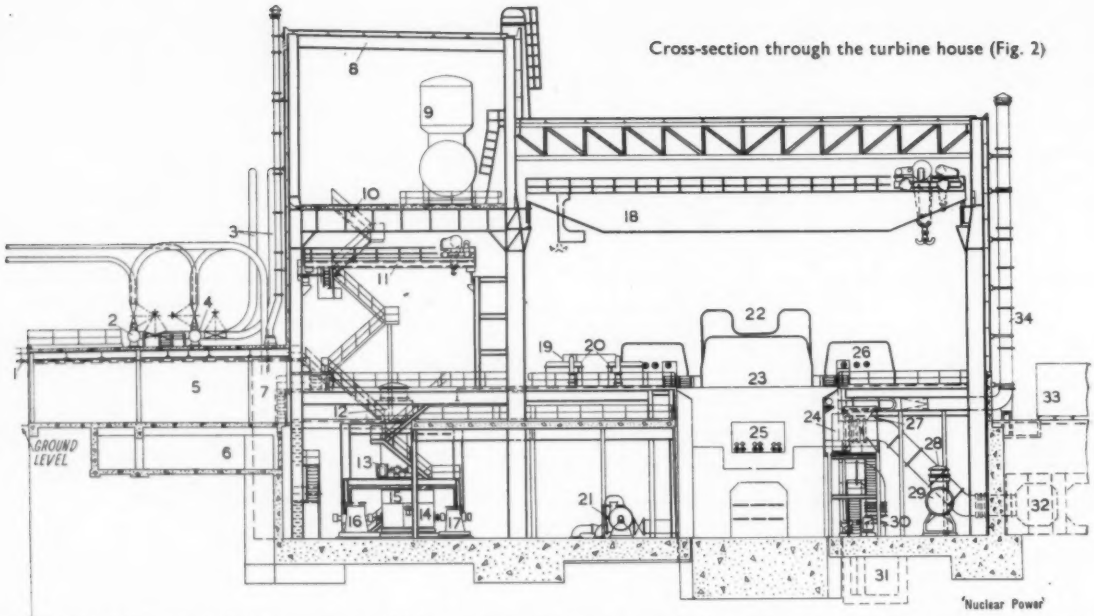
The system was designed to meet all of these conditions after extensive studies of all possible fault, starting and running conditions.

STATION LAYOUT

The site is relatively flat and bounded by woodland on the west and south sides, and open to, but separated from the North Sea, by a low line of hills to the east. It consists of various grades of sands overlying a band of stiff London clay about 200 ft below ground level. The ground water level is about 30 ft below ground level. The foundations for the reactors will be in the form of a raft which, when fully loaded, will have a loading of 3·6 tons per square foot. The ultimate bearing capacity of the sand when loaded by a large raft foundation is very high and the limitations which determine the loading to be put on to the raft arise from settlement considerations.

The buildings have been carefully arranged with respect to one another and the natural features of the site. It was necessary to preserve as much of the woodland as possible as one of the conditions attached to building the station. Every effort has, therefore, been made to achieve as compact a layout as possible (Fig. 3).

The common building for the two reactors, with the Turbine



Cross-section through the turbine house (Fig. 2)

1 personnel bridge; 2 H.P. steam header; 3 crossover pipes; 4 L.P. steam header; 5 electrical annexe; 6 cable race; 7 pipe duct; 8 maintenance runway beam; 9 deaerator; 10 deaerator floor; 11 25/10 ton crane; 12 feed heaters; 13 emergency boiler feed pumps; 14 main boiler feed pumps (15 motor; 16 H.P.; 17 L.P.); 18 two 95/25 ton E.O.T. cranes; 19 No. 2 turbine gauge vacuum boards and supervisory panels; 20 air ejectors; 21 condensate extraction pumps; 22 No. 2 turbo-generator set; 23 turbine operating floor level; 24 rectifier cubicle; 25 bus bar bridge; 26 steam chest; 27 oil tank; 28 oil coolers; 29 seal oil unit; 30 oil pumps; 31 C.W. inlet culvert; 32 C.W. outlet culverts; 33 reserve feed water tanks; 34 atmospheric exhaust pipe

House as close to this building as construction and services space allow, assists very substantially in achieving this objective. The safety fence around the reactor area, a feature of earlier stations, has been eliminated. This has been achieved by designing for a reduction in radiation levels around the outside of the reactor buildings, and by arranging for control of personnel into and out of the reactor building from within the building itself. The ancillary buildings are grouped around the main buildings in a logical and compact manner. It is interesting to note that the area occupied for the station including the switchgear area (indoor gear) when completed will be 24·1 acres, as compared with the Hinkley Point station which (with outdoor switchgear) occupies an area of 38·4 acres.

The Turbine House is sited as close as possible to the foreshore to minimize the length of the circulating water culverts. On the other hand, the pumphouse itself will be built into the line of the hills to make it inconspicuous and to minimize the amount of works on the foreshore.

CIRCULATING WATER SYSTEM

The location of the intake and outfall structures was indicated by the CEGB, following extensive studies of tides and currents by the Board and its consultants.

The coast is protected by a sand bank about 1½ miles offshore, parallel to the coast, which runs about three miles to the north and two miles to the south of the station site. The effect of this bank is to reduce wave heights to a maximum near the shore of about 15 ft. The considerations taken into account in designing the structures offshore were that there should be a minimum of obstruction to the natural movement of the beach and bed material; that the structures would not cause hazards to swimmers or small boats, and that in the construction of the works there would be the minimum amount of interference with the public access to the foreshore fronting the station.

In fact, the only visible structures there will be are the intake and outfall structures offshore and the C.W. pumphouse onshore.

The total circulating water requirement for the station is approximately 27 million gallons per hour; this water is taken to the pumphouse through two intake tunnels each 10 ft 6 in internal diameter and approximately 1860 ft long. The circulating water pumphouse is situated partly in the cliff line and will contain four main C.W. pumps, together with coarse guard screens and drum type fine screens.

The design of the pump suction chamber and screen forebay

Site plan showing compact layout; final area will be 24 acres compared with 38 for Hinkley Point (Fig. 3)

has been determined from hydraulic model tests to ensure satisfactory flows and to reduce the possibility of vortex formation under any conceivable conditions of operation.

The pumps will be of the horizontal spindle, double entry, bottom suction, centrifugal type with direct electric drive, and each pump is capable of handling 113,000 gallons per minute.

To avoid slam pressures which arise from the sudden closure of gravity type reflux valves, butterfly valves will be installed on the discharge side of the pumps. They will be motor operated and will have controlled closure to ensure that the water flow is brought slowly to rest. There will also be butterfly valves on the inlet and discharge sides of the condensers.

Differential level indicating equipment will be installed to detect any excessive drop of water level across the filtration screens due to fouling.

A Goliath crane spans the pumphouse to handle all plant within the structure and a removable roof will be provided over the pump well for access.

The circulating water will be pumped to the Turbine House through two reinforced concrete culverts, one for the condensers of each main set. From the condensers there will be two further culverts connecting with the onshore shaft from which will be taken the two outfall tunnels.

The outfall tunnels are each 10 ft 6 in internal diameter and will be approximately 980 ft in length.

To control marine fouling of the intake system and to prevent slime fouling of condensers and coolers, a chlorination system will be installed. Bulk storage of the liquid chlorine will be provided at the site and it will be delivered by road tanker.

STEAM CYCLE

Electrical power is produced by two 324·75 MW turbo-generators operating at 3000 rev/min, one turbine unit being associated with each reactor. These turbines are, therefore, the largest single turbine units in the world being used for generation in an atomic power station.

The net station output is 580 MW. The bulk of the auxiliary station load is required for the electrically driven CO_2 circulators.

Steam is available to the turbine at the following conditions:

H.P. steam at T.S.V.	646 lbf/in²g: 728·6°F
L.P. steam at T.S.V.	253 lbf/in²g: 728·6°F

The vacuum at full load is 29 in Hg and the final feed temperature 250°F. These steam conditions relate to the minimum design fuel element temperature.

Each turbine unit (Fig. 4) consists of an H.P. cylinder arranged for dual pressure admission and three double flow L.P. cylinders arranged in a single line of shafting to drive the alternator and the a.c. type exciter. High pressure steam admitted to the turbines is expanded to L.P. stop valve pressure before the L.P. steam is also admitted to the turbines and mixed with the partly expanded H.P. steam. To reduce the erosion of the 36 in long blades fitted in the last rows of the L.P. cylinders, two stage steam reheating is used. On each turbine a separate 3-stage feed heating train is provided and the bled steam required for this purpose is extracted from the H.P. exhaust and from two points on the L.P. cylinders. Steam from the three L.P. cylinders passes to a single condenser.

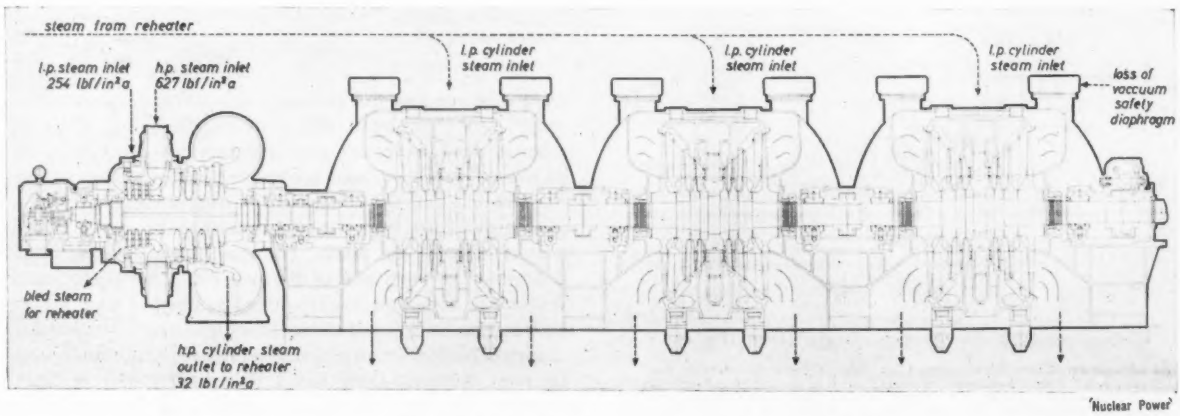
MAIN TURBO-GENERATOR PLANT

Turbine unit

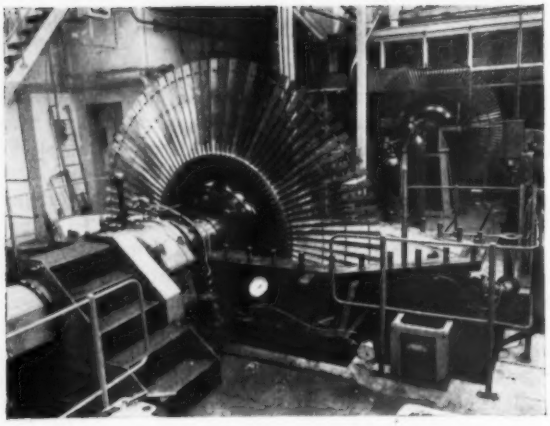
The section through the turbine is shown in Fig. 4. Individual turbine rotors and the generator rotors are joined together by solid couplings and each rotor is supported in two bearings.

The rotors are located axially within the turbine by a single thrust between the H.P. and L.P. cylinders and the turbine casings are anchored to the foundations in a transverse plane coinciding with the plane of the thrust bearing. When steam is admitted and the turbine heats up, the turbine rotors are free to expand axially in both directions from the thrust bearing, while the turbine casings are similarly free to expand axially in both directions from the turbine anchor point. Correct alignment of rotors and casings is maintained by keys and guides.

With the relatively low steam conditions available in an atomic station, the flow to the condenser corresponding to the full set output approaches 2·3 million pounds per hour. Only 1·4 million pounds per hour of steam would be discharged to the condenser on a conventional modern reheat unit of similar output. Consequently, the exhaust area through the last L.P. rows of blading has to be relatively large compared with conventional units in order to reduce the amount of kinetic energy lost in the steam leaving the turbine. Six rows of 36 in last blades on 100 in mean diameter provide a total exhaust of 471 ft². The blade tip velocity exceeds 1·4 × the speed of sound. The English Electric Company will be the first in the world to put such long turbine blades into


steam from reheater
l.p. steam inlet 254 lbf/in²a
h.p. steam inlet 627 lbf/in²a
l.p. cylinder steam inlet
l.p. cylinder steam inlet
l.p. cylinder steam inlet
loss of vacuum safety diaphragm
bled steam for reheater
h.p. cylinder steam outlet to reheater 32 lbf/in²a
'Nuclear Power'

Cross-section through the 324·75 MW mixed pressure turbine (Fig. 4)

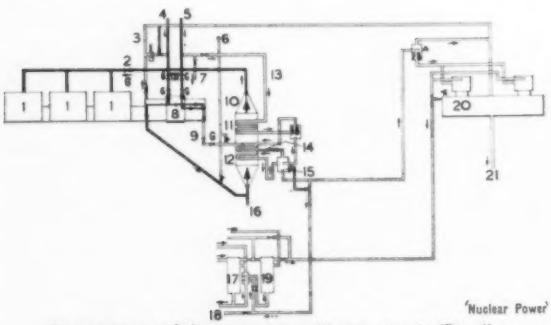


Tests have been carried out on a full size prototype bladed wheel to prove the reliability of the proposed design (Fig. 5)

service at 3000 rev/min and this development represents several years of research, design and testing. Apart from the problems of the flow dynamics which had to be efficiently resolved in order to achieve the best possible performance, mechanical problems arising at 3000 rev/min had to be tackled in a most thorough manner.

Dynamic tests on a full size prototype bladed wheel were carried out to confirm vibration studies of the bladed assembly and generally prove the reliability of the proposed design (see Fig. 5). A pull of 100 tons is exerted by the centrifugal force on each 36 in blade and the selection of suitable blade and disk materials to withstand the stresses involved could only be made after most exhaustive tests had been carried out.

The problem of damage to these blades by erosion by moisture present in the steam when it is expanded to a low vacuum was examined most carefully. To ensure the desired reliability, it was finally decided to reduce the level of the moisture at the end of the expansion to about 8% by the introduction of a two stage steam reheater in the cycle. Figure 6 shows in a diagrammatic form the way in which this is done. Steam which is leaving the H.P. cylinder with approximately 3% moisture content is passed through a surface type reheater where it is dried and superheated. This reheater is supplied with bled steam in the first, and with live steam in the final stage of reheating. Steam for the first stage of reheating is bled from the H.P. cylinder after doing work in the first four stages. Steam for the second stage of reheating is live steam taken from before the H.P. turbine stop valves. Figure 7 illustrates the construction of the reheaters, two of which are fitted with each turbine set.



Arrangement of the two-stage reheater circuit (Fig. 6).

1 L.P. cylinder; 2 interceptor valves; 3 light load L.P. steam to deaerator; 4 L.P. steam; 5 H.P. steam; 6 atmospheric relief pipe; 7 to ejectors; 8 H.P. cylinder; 9 bled steam for reheating; 10 reheater (11 2nd stage; 12 1st stage); 13 live steam for reheating; 14 vent; 15 drain tank; 16 to drain; 17 No. 1 L.P. heater; 18 to condenser flashbox; 19 No. 2 L.P. heater; 20 deaerator storage tank; 21 to feed pump suction; G valves closed by turbine control system

The steam reheater vessels are positioned vertically at the end of the foundation block. Due to the considerable volume of steam to be reheated and the small pressure drop desirable between the H.P. cylinder exhaust and inlet to the L.P. cylinders, twin reheaters in parallel are used, whose heating elements are in shells of 14 ft 0 in inside diameter. Large bore piping carries the wet exhaust steam to the underside of the first stage coils which are supplied with heating steam extracted from the turbine.

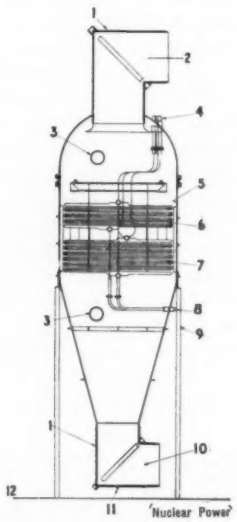
The exhaust steam then passes over the second stage coils which are supplied with H.P. steam. After reheating has taken place the steam passes through overhead pipes to the three double flow L.P. cylinders. The condensate drains from the first and second stage heating coils are taken up to the associated deaerator and provide supplementary feed heating.

This steam drying process is carried out without any loss in performance, because the loss due to using steam for reheating is balanced by gains primarily due to :

1. the increased adiabatic heat drop per lb of steam.
2. the improvement in efficiency of the L.P. turbine associated with reduced amounts of moisture.
3. the use of reheater drains in the deaerator and the use of drier steam for L.P. feed heating.

Condensing and feed heating plant

Under design conditions the condenser maintains a back pressure of 1·0 in Hg at the turbine exhaust. The condensate from each condenser is extracted by a 100% duty extraction pump, backed up by a 100% duty standby pump. The first stage of the pump passes part of the condensate through the generator rotor hydrogen coolers and stator water coolers, the remainder of the condensate passing through a by-pass joining the return from the coolers then to the suction of the second stage of the pump. The third stage discharges the condensate through one of the two 100% air ejector condensers, a flash type drain cooler, numbers 1 and 2 L.P. surface type heaters and thence to a high level, direct contact deaerator heater. Steam is bled from the turbine at three points to these heaters, from the L.P. cylinders to the L.P. heaters and from the exhaust end of the H.P. cylinder to the deaerator.



Section through the steam turbine reheater (Fig. 7).

1 cascade corner; 2 reheated L.P. steam outlet; 3 access manhole; 4 L.P. & H.P. section heating steam inlets; 5 14 ft. 0 in. i.d. shell; 6 reheater H.P. section; 7 reheater L.P. section; 8 L.P. & H.P. condensate outlets; 9 supporting steelwork; 10 L.P. steam inlet; 11 drain nozzle; 12 ground level

The water in the deaerator storage tank supplies the boiler feed pumps.

Steam from the L.P. main steam supply is used in place of bled steam to the deaerator at loads below approximately 40% to maintain the deaerator pressure above atmospheric.

During commissioning, start up and shut down, also in the event of one of the two turbo-generators tripping off load, the deaerators can be used for steam dumping. In principle the dumping method is to pass excess steam from the L.P. and H.P. headers adjacent to the turbine hall direct into the deaerators through suitable pressure reducing and desuperheating apparatus. There are two distinct methods of using the dumping facilities: (*a*) dumping into the deaerator of a shut down turbine, (*b*) dumping into the deaerator of a running turbine.

With a turbine running, the normal deaerator consumption of bled steam is replaced by an equivalent amount of dump steam. If it is required to dump the maximum amount that the pressure reducing valves can pass, then all that is necessary is to by-pass part of the condensate around the No. 2 L.P. heater. The by-pass quantity is so maintained that the decreased condensate heat arriving at the deaerator inlet allows more heat to be absorbed from the dump steam.

When dumping into the deaerator of a shut down turbine, the heat in the dumped steam is removed by the use of a recirculation connexion to the main condenser. The hot water taken from the deaerator is passed to the condenser steam space, where it is flashed off, thus giving up its latent heat to the sea water which is being circulated through the condenser tubes. The return of this re-cooled water to the deaerator is made by the normal condensate extraction pump discharge line via the L.P. heater by-pass. This method of dumping is only acceptable when a reasonable vacuum can be maintained in the condenser of the shut down turbine.

Alternator

The alternator is of the direct-cooled type with a maximum continuous rating of 382 MVA at a power factor of 0·85 lagging. The machine runs at 3000 rev/min and generates at 17·5 kV. It is designed for a short circuit ratio of 0·4.

Two fluids are used in the direct cooling circuits, hydrogen at 45 lbf/in²g for the hollow rotor conductors and stator core, and water for the hollow stator conductors. The hydrogen is circulated by a multi-stage axial-flow blower mounted on the rotor shaft.

Cool gas enters the tubular rotor conductors at each end of the rotor body. The stator core is cooled by another stream of gas which enters it via ducts near one end, passing axially through the core and then flows, together with most of the gas discharged from the rotor, to the first stage cooler and thence to the blower intake. The blower discharges through a diffuser to the second stage cooler, from which the fully cooled gas re-enters the machine.

The thermal design of a water cooled stator winding presents only moderate difficulty, since very low temperature rises are obtained easily, and the circulating system is fundamentally very simple. Each stator coil consists of a number of rectangular copper tubes, and the water for cooling the coils circulates in a closed circuit. Make-up water for stator cooling is drawn from the station demineralized water system when necessary.

The hydrogen coolers, and the heat exchanger in the stator winding water system, are cooled by condensate, so that a large part of the alternator losses is returned to the feed water system.

Excitation system

Excitation for the main alternator is provided by a direct-coupled exciter alternator, the output of which is rectified by a bank of silicon rectifiers feeding directly to the sliprings of the main alternator rotor. Control of the excitation is obtained by means of a continuously acting automatic voltage regulator, which adjusts the rotor current of the exciter alternator. This current is derived through rectifiers from a high frequency alternator coupled to the exciter.

For large unit ratings this system offers important advantages over conventional d.c. exciters; the large speed-reducing gear box is not required, and the maintenance problem of heavy-current commutators and their associated brushgear is eliminated.

Preliminary list of Contractors for Sizewell

English Electric Co. Ltd
Turbo-generating equipment including condensers; feed heating and auxiliary equipment; gas circulators and drives; fuelling machinery; core components; graphite machining; automatic sector rod control equipment; control rod motor electrical supply schemes; electronic control gear; alarm equipment; 11 kV, 3.3 kV and 415 V switchgear; fuse switchgear; fuse distribution boards; electric motors; main control room panels for electrical systems; diesel motor generator sets; main C.W. valves

Subcontractors to English Electric Co. Ltd

Evans Lifts Ltd
Station passenger and goods lifts
The Permutit Co. Ltd
Water treatment plant
Wallace & Tiernan Ltd
Chlorination plant
Hick, Hargreaves & Co. Ltd
Ejectors
Drysdale & Co. Ltd
C.W. pumps
J. Blakeborough & Sons Ltd
C.W. cross-connexion valve
F. W. Brackett & Co. Ltd
Drum screens
Mather & Platt Ltd
Boiler feed pumps
Corrosion & Welding Engineering Ltd
Fire fighting equipment and cathodic protection equipment
Pyrotenax Ltd
Thermocouples
Thos. Firth & John Brown Ltd
Turbine forgings
Stanton Machine Tools Ltd
Machine tools
Atomic Energy Authority
Graphite

Babcock & Wilcox Ltd
Reactor pressure vessels; boilers; gas ducting; 400-ton Goliath and other cranes; fuel-handling equipment; main steam-feed pipework; turbine reheaters; shielding and shuttering

Sub-contractors to Babcock & Wilcox Ltd

Bailey Meters & Controls Ltd
Feed water regulators
Bairds & Scottish Steel Ltd
Support steelwork for boiler heat-exchange elements
William Beardmore & Co. Ltd
Pressure-vessel nozzle forgings; gas circulator ring forgings
Brooke Marine Ltd
Shielding and shuttering
Colvilles Ltd
Core support steelwork; reactor pressure vessel plating
Dewrance & Co. Ltd
Heat-exchanger mountings; steam and feed pipeline valves; parallel slide valves; large bore strainers; safety valves; water level indicators; small bore valves
Engineering Appliances Ltd
Bellows convolutions
English Steel Corporation Ltd
Boiler plating
Hayward Tyler & Co. Ltd
Boiler circulating pumps
Hopkinsons Ltd
Main CO_2 valves and actuators
John Rigby & Sons Ltd
Strip for heat-exchange element tube studding
Sigmund Pumps Ltd
General service and water pumps; clean drain pumps; turbine house sump pumps

Taylor Woodrow Construction Ltd
All civil engineering work of the reactor building, turbine hall, pumphouse and remainder of site works

Sub-contractors to Taylor Woodrow Construction Ltd

Braithwaite Structural Co. Ltd
Structural steelwork
G. N. Haden & Sons Ltd
Heating and ventilating
International Paint Co. Ltd
All paints
Arcon Group
Temporary industrial structures
Swiftplan Ltd
Temporary offices and camp
Martin Cowley Ltd
Bulk scraper excavation
Escay Ltd
Temporary fencing
Steels Ltd
Permanent cranes on offshore structures
George Stow Ltd
Deep well dewatering
Wessex Coaches Ltd
Labour transport
Terresearch Ltd
Site investigation

Points from Papers

reports, meetings, conferences

FUEL ELEMENT STRESSES

The coolant flowpath in the core of the *N.S. Savannah* reactor (which consists of groups of four fuel rod bundles in stainless steel cans) causes a net internal pressure on the peripheral cans. These must be designed so that there is no interference with control rod operation or with fuel rod bundles by deflection or deformation of the can walls. A calculation procedure has been developed to evaluate the stresses and deflection of a square cross-section container subjected to internal and external pressure on the walls but not on the ends. The procedure is reported in this paper together with associated experimental work.

The stress and deflection characteristics of N.S. Savannah-type fuel element containers due to internal-to-external pressure differentials. T. A. Hughes and D. L. Mayer. Babcock and Wilcox Co. Research Center. 58 pp. Paper presented to the 1961 Annual Meeting of the American Nuclear Society. Copies available from *Nuclear Power*.

URANIUM CARBIDE

Of all the refractory uranium compounds carbides show promise as fuel materials superior in some respects to UO_2. The USAEC has initiated a number of contracts; these include research on preparation and fabrication of uranium carbides, determination of physical and chemical properties, irradiation testing, fuel element design, fuel recycling etc. There are also a number of specific design projects under way of reactor systems fuelled with uranium carbides. The work reported here was presented at the third AEC Carbide Meeting Dec. 1960.

Proceedings of the uranium carbide meeting held at Oak Ridge National Laboratory, Dec., 1960. Report TID-7603. 162 pp. Available from OTS $1.75 or from the depository library.

ECONOMIC STATUS OF BWR's

Reported technical advances in the operation of the VBWR and Dresden have reduced significantly estimated power costs for central station BWR's. The paper reports that it is possible to design and build 400 MW plants at $183/kW for start up in 1965. Among the advances reported is the increase in plant rating, internal steam separation and pressure suppression. The paper also reports that a dual cycle 500 MW plant could be built for $176/kW.

The technical and economic status of central station boiling water reactors. R. B. Richards. Atomic Power Equipment Department, General Electric Company. 22 pp. Copies available from *Nuclear Power*.

CONTROL SYSTEM FOR ML-1

The ML-1 is a prototype, transportable, closed-cycle, gas-turbine power plant capable of producing 300-500kWe. The control cab is designed for one-man operation; 3-ton maximum weight; and can be located 500 ft from the reactor. The plant control system is manual for start-up and shutdown. For steady-state operation there is automatic control through two servo loops, the turbine-compressor set speed and the reactor outlet temperature. For reactor control, there are six pairs of semaphore-type control blades at the core circumference. They are actuated by electromechanical devices at the edge of the shield water tank. Five of them are for shim-scram service; the sixth controls gas outlet temperature.

Control system for the ML-1 nuclear power plant. H. DeCovnick. Aerojet-General Nucleonics. **Report AN-ENGR-17.** 26 pp. Copies available from *Nuclear Power*.

RADIOACTIVE WATER PURIFICATION

The paper outlines a method of reducing the cost of reactor auxiliary systems (for BWR's) by having an integrated radioactive water purification plant. Hitherto the reactor water, fuel element storage pond water, shield cooling water, etc. have been treated for separately. As they are essentially the same kind of water, a single system would do away with plant duplication.

An integrated radioactive water purification and cooling system for boiling water reactors. J. H. Noble. Atomic Energy Division, Allis-Chalmers Mfg. Co. **Report 43 R 9991.** 3 pp. Paper presented to the 1961 Annual Meeting of the American Nuclear Society. Copies available from *Nuclear Power*.

NEW TAGGING TECHNIQUE

The method of using radioactive decay for determining time intervals suffers from the difficulty of having accurately comparable samples and maintaining equipment calibration over a period of time. An accurate method has been developed at The Goodyear Tire and Rubber Co. which uses two isotopes. One of the intrinsically mixed pair has a relatively long half-life and thus serves as a reference standard. The other has a half-life related to the time interval it is wished to measure and acts as the timer. It is reported that time intervals can be measured with an error not exceeding $\pm 5\%$. The feasibility of the method has been successfully demonstrated.

A new tagging technique for measuring slow flow rates and material dwell times. T. C. Gregson and S. D. Gehman. The Goodyear Tire and Rubber Co. 26 pp. Copies available from *Nuclear Power*.

FUEL HANDLING IN OMR's

The fundamentals to be used for the fuel handling system at Piqua are described. Several designs were considered; the one finally selected uses a drum and tape with a grapple pickup device. Effort is also being made by this company to develop on-load refuelling and systems are being studied which use internal fuel handling equipment where it is unnecessary to remove the reactor tank covers. The description in this report is of the tests carried out on shutdown fuel handling equipment.

Fuel handling procedures for organic moderated reactors. C. M. Keim. Atomics International. 6 pp. Copies available from *Nuclear Power*.

PM-1 ZERO POWER TESTS

There were two main parts to this zero power test programme. The first was a study of the basic parameters associated with the analytical study before the actual core design; the second was a zero power test programme to confirm the final design. This programme, described in detail in this paper, used a core which was a mock-up of the PM-1 design and was in three phases. The first determined the nuclear characteristics of the preliminary configuration. This data was then used to modify the configuration on the basis of the design requirements. Work on this second phase led to the final design which was studied in the third phase.

Portable medium power reactor no. 1 (PM-1) zero power experimental studies. H. B. Rosenthal. The Martin Company. 15 pp. Paper presented to the 1961 Annual Meeting of the American Nuclear Society. Copies available from *Nuclear Power*.

New Reports

Tritium detection and measurement, a bibliography. A. C. Foskett. AERE Harwell. **Report AERE Bib 132.** 33 pp. Available from HMSO 5*s*.

The analytical chemistry of beryllium, proceedings of a symposium held in Blackpool 1960. Edited by J. Metcalfe and J. A. Ryan. UKAEA Springfields. **PG Report 171 (S).** 180 pp. Available from HMSO 12*s* 6*d*.

Oxides of europium, gadolinium, praseodymium and samarium. Bibliography compiled by P. J. Jones. AERE Harwell. **Report AERE Bib 130.** 28 pp. Available from HMSO 4*s* 6d.

Investigation of BF_3 proportional counters. H. F. Brinckmann & D. Gerber. Translated by E. Franklin from *Kernenergie*, 1960, **3**, (4), 309-314. **Report AERE Trans 859.** 13 pp. Available from the Library, AERE Harwell.

A report on the first loading of Zenith. R. M. Absalom *et al.* AEE WINFRITH. **Report AEEW R 50.** 78 pp. Available from HMSO 11*s*.

Energy deposition and radiation damage in organic cooled reactors. J. D. Jones. AEE Winfrith. **Report AEEW R 52.** 32 pp. Available from HMSO 5*s*.

Estimated densities of plutonium and hydrogen for use in criticality calculations. E. E. Jackson & E. Wait. AERE Harwell. **Report AERE M 802.** 5 pp. Available from HMSO 1*s*. 9*d*.

Uranium carbides. Bibliography compiled by P. J. Jones. AERE Harwell. **Report AERE Bib 129.** 25 pp. Available from HMSO 4*s*.

'Nuclear Power' INFORMATION

The papers reviewed here represent only a very small selection of those acquired and read by *Nuclear Power*. If you hear of a paper and have difficulty in obtaining a copy, write or telephone *Nuclear Power* Information Bureau, 77-79 Charlotte Street, London W1, MUSeum 8252.

STUDENTS' NOTEBOOK

GROUNDWORK—Teaching

Is highly specialized training really necessary?

With examinations safely behind him a student, reflecting on the course just completed, could well ask himself if he has been 'educated' or formally trained for a particular career. In most cases, of course, the immediate aim is to 'qualify' and once a student has chosen his career it little profits him to question the value of the set curriculum. He takes the system as he finds it and attempts to conform to it. After all, he thinks, he can always educate himself when his formal studies have been completed.

An engineering student, for example, whether in technical college or university, studies a limited range of subjects: theory of machines, strength of materials, applied thermodynamics and the like, which it is assumed, are most relevant to his engineering future. This course, it should be noted, is not only strictly vocational but covers an extremely narrow field. Since even directly associated vocational studies such as chemistry, physics and, say business management, are neglected it is not surprising that more academic subjects, for instance, the history of science, are completely ignored. Yet what engineering student could fail to profit from a study of the logical development of the laws of motion from the observations and deductions of the ancient astronomers?

Is it possible to liberalize the highly specialized courses which have become accepted as the yardstick for employment? Time at college is short and there is much to learn if the student is to have an advanced knowledge of the basic engineering subjects. But must the student have this specialized knowledge? What use is it except when directly applied, and what use is a highly specialized person outside his own field? One survey made in an American college showed quite a low correlation between the subjects studied at the college and the work the student did in business afterwards, so a high degree of specialization hardly seemed warranted.

In the age of rapid diversification, with its inevitable interlacing of the numerous branches of science the narrowness of most study programmes becomes increasingly apparent. There are, for example, hundreds of 'qualified' engineers in the nuclear business who do not know what a chemical element is, let alone understand the significance of the periodic table, and who do not have even an elementary knowledge of the structure of matter. Some indeed, who might be capable of quite complicated exercises in mechanics, would have great difficulty in defining 'mass'.

Engineers are not the only people who receive narrow, strictly vocational training, and this article refers to them only in as much as they provide a familiar example. In the United States of America it is possible to obtain first and higher degrees in the many business management schools associated with universities. In these the training is restricted only to subjects strictly concerned with the detailed functions of management and if a non-vocational subject slips in it does so in disguise. English, for example, now becomes 'Communication Skills'. It is significant that, although such graduates may have advantages when they first enter the business world, after about five years they are overhauled by people educated in the liberal arts.

NEWS

• The nuclear reactor grants to the Scottish Universities, Liverpool and Manchester Universities, and London University, due to be included in DSIR's estimate for 1962/63, have been suspended at least up to November (See *Worldview*, this issue).

• Full-time non-professional supporting staff employed on radiation health and safety duties are to have a basic qualification. The City and Guilds of London Institute have introduced a new examination and the course envisaged will be a part-time one of at least 225 hours, 45% of which will be spent on practical work.

• Glasgow's Royal College of Science and Technology now has its new high voltage laboratory. Built at a cost of £30,000 the building's main facility is the impulse generator capable of producing a 1½ million volt surge which rises to its peak in one-millionth of a second.

• To encourage diversity in the training of chemical engineers, the Institution of Chemical Engineers has prepared a new scheme for a postgraduate course.

• Tracerlab has announced the availability of a coloured wall chart depicting the distribution of ionizing radiation in outer space.

• Thirty-seven different student experiments on a cathode ray oscilloscope, covering electrical, magnetic, sound and properties of matter measurements, are described in a new publication from Mullard.

• A 'reasoning machine' capable of independently reading, abstracting and classifying nuclear energy scientific publications, and reproducing the result in the required language, is the subject of a new Euratom project. In charge of preliminary scientific feasibility investigations is professor Beth of the University of Amsterdam.

• Among American scientists visiting Europe this year to pursue one-year specialized studies is Westinghouse physicist, Dr B. S. Chandrasekhar, due for Imperial College. Mr S. L. Ruby, also from Westinghouse, will continue his studies on the Mössbauer effect at the Weizmann Institute, Rehovot, Israel. At the Copenhagen Institute for theoretical Physics, to study photonuclear reactions and the theory of nuclear beta decay respectively, are Dr E. Hayward and Dr R. W. Hayward a husband and wife team of nuclear physicists from the US National Bureau of Standards.

FILMS

• *Conquest of the atom.* 22 minutes (colour).

• *Ultrasonics.* 21 minutes (black and white). Both films, on hire from Mullard Ltd, Torrington Place, London, W.C.1, have been selected by the British Film Institute for the National Film Archives.

• *Technical information services of the AEC.* 20 minutes (in colour). 16mm. Includes details of the wealth of information available in the USAEC depository libraries. Free hire from the AEC Office at the American Embassies in London, Brussels, Buenos Aires and Tokyo.

The following films, suitable for teaching up to GCE Ordinary and Advanced Levels, are available from the G.B. Film Library, 1 Aintree Road, Perivale, Greenford, Middlesex. Hire charge: 10s each reel.

• *Atomic energy.* 1 reel, 11 minutes (black and white). (Encyclopaedia Britannica). Explains principles by animated diagrams, photographs and graphs.

• *Atomic physics* (in five parts). 10 reels, 89 minutes (black and white).

• *The linear accelerator.* 1½ reels, 12 minutes (black and white).

• *X-rays.* 2 reels, 14 minutes (black and white). (Czech Film Institute). Comprehensive account of the nature of X-rays and their use in medicine and industry.

UK COURSES

Battersea College of Technology, London Principles and practice of radiation protection, 1 year diploma course commencing October, Fee: £34.

Birmingham College of Advanced Technology First part of the Harwell course, 9 weeks, commencing September, Fee: £60.

Bradford Institute of Technology First part of the Harwell course, 9 weeks, commencing September.

Chelsea College of Science and Technology, London 1 or 2 years M.Sc. courses commencing September: Nuclear physics, Physical electronics, Solid state physics, Fee: £30.

Lanchester College of Technology, Coventry Nuclear physics, evening course on Thursdays October 5—December 21, Fee: £1 2s.

London University, Bedford College Beta and gamma ray spectroscopy, 1 year diploma course commencing October, Fee: £47 5s.

Salford Royal Technical College Radiological health and safety, 1 year certificate course commencing October, Fee: £81.

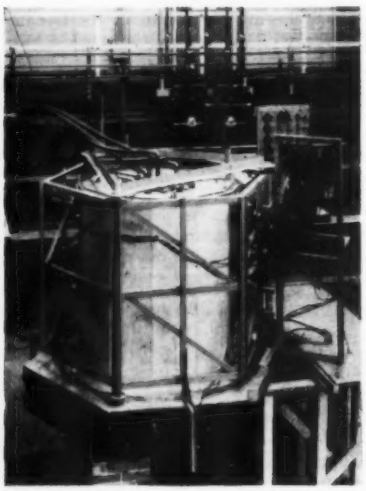
First part of the Harwell course, 9 weeks, commencing September.

Sir John Cass College Radiochemistry for post-graduate students, 1 year diploma or M.Sc. course, commencing October, Fee: £36.

Prestressed concrete in reactors

Temperature and radiation effects

Working in collaboration with the UKAEA, the Building Research Station, Watford, are investigating problems relating to the possible use of prestressed concrete in future nuclear power stations. One important aspect of prestressed concrete pressure vessel construction under examination is the effect of irradiation, particularly on the relaxation of stress in prestressing wires. Limited space in the reactor presented a problem but this has been overcome by stressing the wires in tubes and determining the stress by measuring their frequency of vibration. In this way, six specimens can be irradiated simultaneously in a cavity of 3½ in dia.



In collaboration with Taylor Woodrow, this 1/20 scale model of the Hinkley Point shield, erected at the Building Research Station, is being used for preliminary studies of temperature effects on concrete (*DSIR photograph*)

The programme in hand has as its target the measurement of the loss of stress for different initial working stresses over a period of 10,000 h. Results so far, with different types of wire, indicate that for periods up to 1000 h at 120°C the loss of stress may be as much as 20% for wires stressed initially to the maximum and that the loss is significant even at temperatures a little over 18°C. An important recent development in prestressing techniques is the use of strand for both pretensioning and post-tensioning.

Temperature effects create other problems and the studies being made include the forces required to restrain bending of concrete beams, moisture transfer and drying shrinkage effects, and the general properties of shield concretes made with various aggregates. Using models of the Hinkley Point shield, with a wall thickness of 4·2 in, preliminary studies have been made of temperature effects; the temperature gradients through the walls are simulated by electrical heating within the concrete combined with spray cooling of the inner and outer concrete surfaces. Drying shrinkage effects are also to be investigated. Other observations are being made at Berkeley and Bradwell; so far these show that the temperature gradients within the concrete thermal and biological shield are lower than at first expected and that, as a consequence, little drying has as yet occurred in the interior of the concrete walls.

★ 280

Reactor fuel development

new BeO coating process

NUMEC claim that they have achieved successful deposition of a coating of non-porous beryllia on small particles of uranium dioxide in layers—up to 100 microns on 100 micron diameter particles.

The new process opens up the possibility of obtaining very uniform cermet, ceramic in ceramic, ceramic in metal, metal in ceramic, and metal in metal fabricated parts and pieces for a variety of applications requiring high temperature, corrosion-resistant, thermal-shock-resistant materials. With coated reactor fuel particles, the following major improvements in fuel element design are possible: better retention of fission products; improved thermal conductivity; higher fuel densities; increased resistance to corrosion, erosion, abrasion, and irradiation damage; and greater dimensional stability.

Beryllium oxide coatings are particularly attractive for high power propulsion reactor systems, such as those in nuclear rockets.

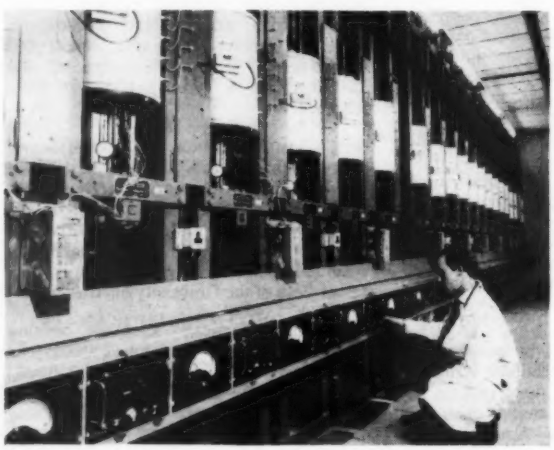
★ 281

New creep laboratory

ERA's programme extended

The new Creep of Steel Laboratory, recently opened at the Electrical Research Association's Leatherhead site was built because the test programme on steels and creep resisting alloys sponsored by the E.R.A. at the N.P.L. was severely extended. The new laboratory, which will be mainly concerned with long-term tests of the order of 20,000 h or more, consists of a windowless block with heavily insulated walls and roof. Multiple air changes keep the internal temperature reasonably constant and dissipate heat from the furnaces.

The photograph shows a typical bank of furnaces used for dial gauge creep measurements. These are dual purpose machines, 25 being used for creep tests and 25 for 3-specimen multi-rupture tests. Other equipment includes 50 high-sensitivity machines fitted with optical extensometers, 50 ten-specimen rupture machines and one 15-ton machine for testing specimens from the full thickness of steam pipes. The high sensitivity machines measure creep



One of the electronic temperature controllers for the E.R.A. creep furnaces is being adjusted. These are actuated by platinum resistance thermometers. The temperature of each furnace, transmitted to a central control desk, is measured by either three or five thermocouples tied to the specimen

properties of rotor forgings; the other machines test castings from turbine casings.

High temperature steels for pipes and superheater tubes are tested in the multi-rupture machines. The rupture properties obtained in these uniaxial stress tests are correlated with tests on thick-walled tubes subjected to internal steam pressure at high temperature. Eleven such rigs have been installed, supplementing the four that have been in operation for several years.

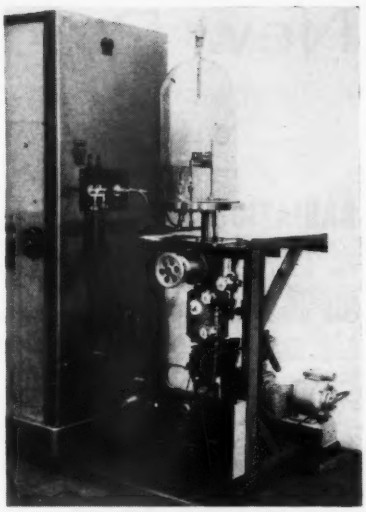
★ 282

Brazing in vacuum

r.f. induction heater used

A technique of fluxless brazing that has unique advantages over other methods and uses radio frequency magnetic fields in high vacuum, has been developed at the UKAEA Capenhurst Laboratories. The absence of flux, together with the reduction of surface oxides and the degassing of the metal occurring at brazing temperatures, makes any subsequent chemical or mechanical cleaning unnecessary. Chemical and physical standards of the finished components are also improved.

The apparatus consists of a 9 kW Redifon induction heater, a vacuum chamber of internal diameter 9–12 in and height 12–21 in, and a 2 in dia. silicone-oil diffusion pump backed by a rotary oil pump. This combination is necessary to achieve an operating pressure of around 10^{-6} mmHg. The r.f. magnetic field is defined by a copper coil that can vary from 1–5 turns. This produces eddy currents in the metal work piece. The chamber is ideally suited for work in which the region to be heated does not exceed around 2 lb in weight, a maximum diameter of 4 in and a height of 12 in.



The Capenhurst fluxless brazing equipment consists of a pump kit, a 12 in dia by 18 in high vacuum chamber, coupled to a radio-frequency induction heater

Inflexible capillary tubes up to 15 ft have been accommodated, however.

Temperature distribution in the components can be controlled either by varying the location of the components inside the coil, in which case the work is supported on a movable platform remotely controlled from outside the chamber, or by varying the rate of supply of the r.f. power.

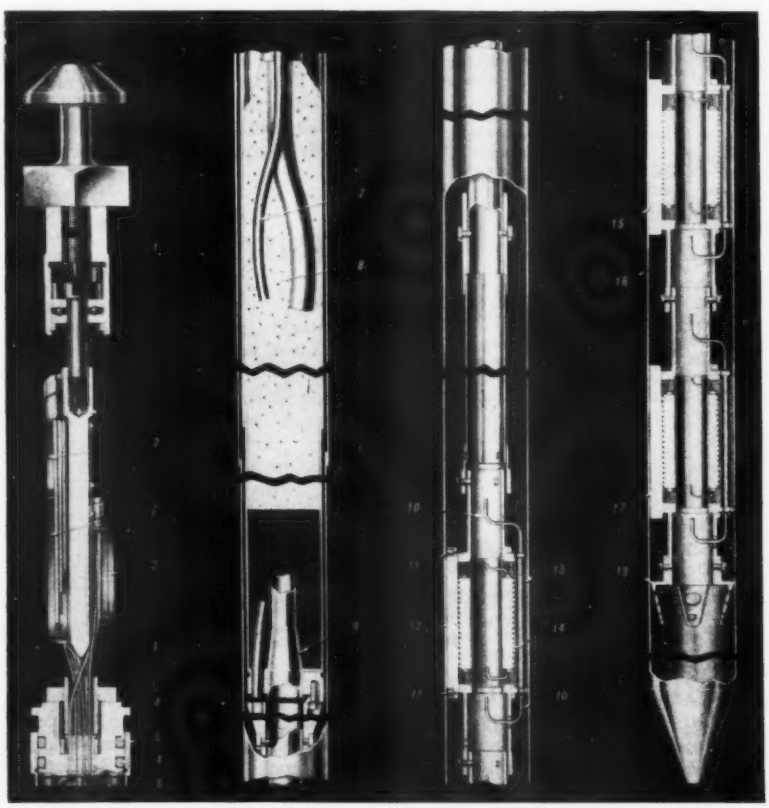
(For further information see: DEG Report 300 (CA), obtainable from HMSO, 3s)

★ 283

GRAPHITE IRRADIATION RIG

This Harwell rig, typical of the 50 or so in current use at the four reactors Bepo, Pluto, Lido and Dido, has been specially designed for graphite specimens. The three magazines allow irradiation for a set time at three different temperatures. The rig is then re-used to irradiate new specimens for a different period at different temperatures

1 removable load/unload attachment; 2 heating connexions and thermocouples; 3 rig shield plug; 4 O-ring seal; 5 thimble; 6 cable seal; 7 helium supply pipe; 8 shield plug; 9conduit for leads and thermocouples; 10 thermocouples; 11 locating spigots; 12 no. 1 magazine; 13 graphite specimen; 14 heater coil; 15 no. 2 magazine; 16 thimble; 17 no. 3 magazine; 18 lead-in spider ★ 288



IN BRIEF

ACTIVATION ANALYSIS Using a deuteron accelerator, the Shell Development Co. have developed radiation techniques for the chemical analysis of trace elements in petroleum.

★ 284

GAMMA RESEARCH By acquiring a 50,000 cobalt−60 source, the US National Bureau of Standards has increased its gamma-ray capacity by a factor of 25. Research will be carried out on gamma effect on fluorocarbons, the production of radicals at low temperature, and the relation between radiolysis and photolysis.

★ 285

POWER PLANT START-UP Thorium/beryllium neutron sources in pellet form, contained in welded stainless steel cans, will be used to start up Bradwell and Berkeley. Because of their larger size, inactive antimony/beryllium sources will also be provided but these will only become effective after irradiation on site.

★ 286

PERIPHERY PHOTOGRAPHY Photographs of irregular and curved surfaces can now be taken with the new periphery camera developed at Shell's Thornton Research Centre. Surface texture details, wear marks and small surface deformations, on one negative, appear clearly.

★ 287

★ For further information on any item, circle the appropriate number on the reply card facing page 106.

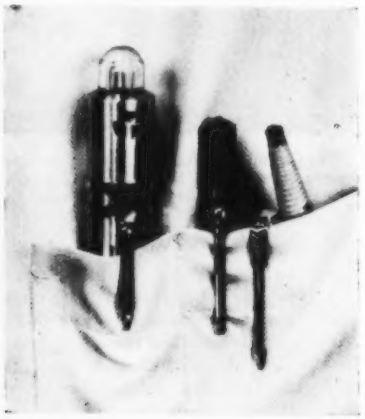
New Product Survey

EQUIPMENT · INSTRUMENTS · MATERIALS

RADIATION MONITOR

new pocket type

The latest addition to Numec's line of personal radiation monitors, made for Oak Ridge National Laboratory, weighs 3·5 oz and provides continuous audible and



Numec's personal radiation monitor, PRM, 5¾ in long by ¾ in dia., operates in the ambient temperature range —20° F to 120° F, and works from a standard 4V mercury battery

visible indication of radiation levels. The repetition rate of the warning tone and the flash is proportional to the gamma dose rate.

Two instruments are available covering both low and high radiation ranges. PRM-1 is most effective for the range from 1 mr/h to 2 r/h, with a continuous wail at higher levels. PRM-2 is intended for the 10 mr/h to 200 r/h range although it provides a proportionate indication from background to 10 mr/h and gives a continuous wail at levels over 200 r/h. Cased in stainless steel, the monitor uses a miniature halogen-quenched G.M.tube.

A similar device, the Self-Contained Radiation Monitor (Scram I), based on an Oak Ridge design, has been introduced by Radiation Equipment.

★ 208

NEW COMPACT SEAL

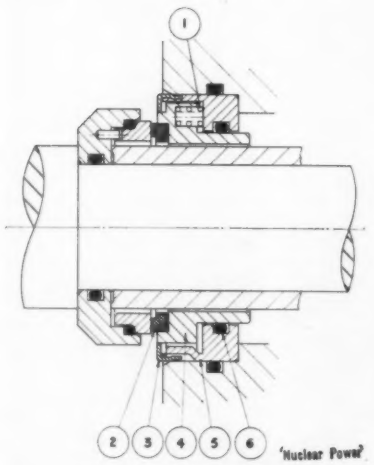
high speed shaft sealing

A new mechanical seal, the type DD, introduced by Flexibox for high speed shaft applications, caters for peripheral speeds up to 15,000 ft/min, pressures up to 1000 lbf/in²g, and temperatures up to 500°F.

All components are replaceable and worn parts can either be replaced completely or reconditioned without destroying the whole seal. In addition, the overall length can be specified to close tolerances. The complete seal unit is designed as a press fit in its housing and the smooth clean profile of the outside diameter and rubbing face ensure accurate leak-free fitting. Typical applications are: air and gas blowers, hydraulic pumps and motors, chemical pumps, and gas seals.

The DD seal is a face-type balanced mechanical unit of multi-spring design. It consists essentially of a housing which carries a resiliently-mounted stationary rubbing face assembly. Face loading is provided by a number of small springs arranged around the flange of the stationary seal ring body; this ensures close control and uniform application of the face contact pressure.

The basic design is available in three types: O-ring fitted, chevron packed and 'reverse balanced'. Each basic type is also available in two ranges of axial tolerance and three face loadings. Whilst shaft diameters from ¼ in to 8 in are covered by the standard range, larger diameters can also be manufactured.



A Flexibox type DD mechanical seal for sealing high-speed rotary equipment

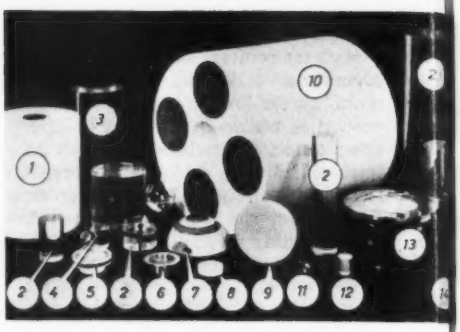
1 Springs; 2 Stationary seal ring inset 3 Housing cap 4 Stationary seal ring body 5 Seal housing 6 Stationary seal ring packing.

★ 209

SCINTILLATOR DEVICES

wide range available

The range of scintillation detectors now produced by Nuclear Enterprises varies from 1 mm thick for X-ray detection to the



Nuclear Enterprises' range of radiation detectors

1 gamma plastic scintillators 2 plastic scintillator rod and cylinders 3 anti-coincidence shield 4 encapsulated liquid scintillator 5 burst slug detector 6 B-10 liquid scintillator cell 7 NE812 A flow cell for beta spectra 8 fast neutron detector NE450 9 fast neutron detector NE451 10 scintillation phosphor 16 in by 16 in 11 1 mm NaI(T1) crystal 12 1 in by 1 in NaI (T1) crystal 13 NaI (T1) crystal 14 plastic phosphor sphere

NE 102 plastic phosphor 16 in dia. × 16 in long. Recently introduced (No. 6) is the NE 411 slow neutron liquid scintillator detector. This consists of an NE 311A boron loaded liquid scintillator, enriched in B-10 to 90%, in special thin glass cells with indium gaskets, giving liquid thicknesses of 1·7 mm.

Another recent item is the 6 in × 4 in NaI(T1) crystal (No. 13). Together with three other crystals of similar size, it will be used in the human body monitor head units being constructed for Leeds General Infirmary. NE plastic phosphor spheres are to be used for measuring cosmic radiation (No. 14). Incorporated in an Imperial College designed instrument, they will shortly be carried in a US Scout rocket.

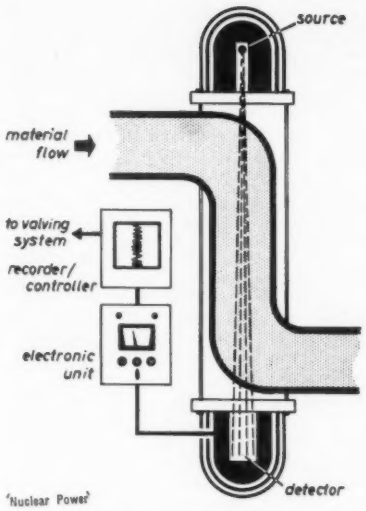
★ 210

DENSITY GAUGE

uses radioactive source

Continuous measurement of specific gravity of solutions or slurries in process pipes, accurate to within 0·0001 are possible with Nuclear Chicago's new Qualicon liquid density gauge. The system consists of two basic components: a measuring head which is installed at the chosen point in the process stream, and an electronic read-out unit which displays the process variable (specific gravity, % solids, etc.) on a permanently-calibrated panel meter in terms of the process. No reference to curves or calibration information is required.

The measuring head carries a caesium-137 source and the gamma rays produced pass through the measured material, are detected by the Dynacell radiation chamber and converted into an electrical current. The d.c. current from the Dynacell is inversely proportional to the density of the material. Two basic heads are available: a single unit for installation as a pipe



The Nuclear-Chicago liquid density gauges can be used on pipes or tanks ranging from 1 in to 36 in dia. The Duo-unit, consisting of separate source and detector units, can be installed on either vertical or horizontal lines

section, and a two-piece assembly that can be strapped to pipes or other containers up to 36 in diameter.

★ 211

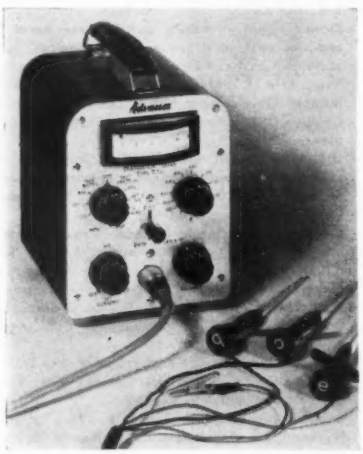
TESTING TRANSISTORS

in circuit operation

Advance Components have developed a transistor tester, the T.T.I., for testing low and medium power p.n.p. and n.p.n. transistors while still in circuit. Grounded emitter current gain may be measured in or out of circuit and leakage current (grounded emitter) with the transistors out of circuit.

The set current is normally 1-10mA but 10mA is not obtainable with transistor betas below 12; 1mA is not obtainable with transistor betas greater than 200. Shunt collector circuits of greater than 100Ω may be balanced out. Transistors having a leakage current of from 0-1mA and 0-100μA can be measured. The circuit is protected so that the maximum battery drain is 110mA and the meter is protected for overloads of greater than 500%.

★ 212



The T.T.I transistor tester from Advance Components prevents the risk of component damage by testing transisitors in circuit

VOLTAGE MEASUREMENT

print-out facilities

For setting up in electronic installations, with standard 19 in rack mounting, Solartron now have a flush panel version digital voltmeter, the LM 902.2R. Direct current voltages from 100μV to 1·599 kV are presented as a four digit display in decimal form with polarity discrimination; display is by means of optical projection.

Voltage measurements are covered in five ranges. The input impedance is 10 MΩ, except on the two lower ranges, which have impedances of 1 MΩ and 100 kΩ. Two additional high impedance voltage ranges of 100V and 1 kV have input impedances of 100 MΩ. The read-out time is constant at 280 milliseconds irrespective of the voltage input, which may be 'floated' up to 700V with respect to earth.

Under normal (Auto) operation, voltages are measured continuously, any variations causing the instrument to display a new reading. When switched to 'Sample,' a single voltage reading is displayed and this will remain until a succeeding sample is taken.

★ 213

The Solartron four-figure rack-mounted digital voltmeter provides print-out facilities

IN BRIEF

• **Radiation thermometers.** Designed for measuring temperature without physical contact, is the 'Thermodot' marketed by West. It operates on the response of an infrared detector which generates a signal voltage accurately proportional to the radiation density. Model TD-1, for research work, will function from 100°F; TD-3, for industrial use, operates from 180°F.

★ 214

• **Moisture indicator.** Using small capacitance type sensing elements, the new Shaw hygrometer alarm detects the slightest trace of moisture in gas or air. The sensing element can be several hundred yards away from the instrument; the maximum temperature rating is 180°C.

★ 215

• **Water purifier.** The Mark 7 portable 'Deminrolit' unit from Permutit produces about 16 gal of purified water (London type) per cartridge. This is a detachable component containing a bed of intimately mixed Zeo-Karb cation and De-Acidite anion exchange materials.

★ 216

• **Flexible tubing.** Jetflex, a stainless steel corrugated tubing produced by Power Flexible Tubing, has successfully passed tests that meet all the stringent requirements specified for modern aircraft.

★ 217

• **Induction furnace.** Edwards High Vacuum's medium size furnace is now available with a coil assembly of 100 lb steel capacity. The melting capacity is fully interchangeable using either a 28, 56, or 100 lb coil assembly.

★ 218

• **High speed recorder.** Up to 14 independent channels are available in the new ABEM ultragraph for the direct recording of high speed physical phenomena within the frequency range of d.c. to 5000 c/s. The recorder employs a high pressure mercury vapour lamp and recordings are made on ultra-violet sensitive paper.

★ 219

• **Corrosion control.** Using the principle of increased electrical resistance with increased corrosion, the Corrosometer, marketed by Winston Electronics, can be used on all metals and alloys and gives a direct reading in micro-inches or cm in less than a minute. Three probes are used, construction varying according to environmental conditions. One probe goes to the test area, the other two are protected reference specimens.

★ 220

• **Ultrasonic cleaning.** A new 3500 W ultrasonic generator, Model LG-3500A 'Sonogen,' with a peak on pulses of 7000 W, has been introduced by Branson. It automatically adjusts itself to variations in cleaning load, solution temperature, and tank volume.

★ 221

• **Leak detector.** CEC's Type 24-510 Radiflo leak detector can work in the 10^{-11} atm cm³/s range and is capable of testing hermetically sealed components such as transistors, diodes, crystals, etc. Krypton-85 under pressures up to 200 lbf/in²g is used during the chamber flooding stage.

★ 222

• **Pressure measurement.** Consolidated Electrodynamics' Type 4-350 transducer, designed for rugged use, has a pressure range from 0-100 lbf/in² to 0-5000 lbf/in² and an operable range —320°F to 300°F.

★ 223

★ *For further information on any item, circle the appropriate number on the reply card facing page* 106.

ISOTOPE REVIEW

NEW TECHNIQUES

Low cost Co-60 units

New low-cost units for laboratory experiments with Cobalt-60, developed by Atomic Energy of Canada Ltd., are now available in the UK from Watson & Sons (Electro-Medical) Ltd. They are the Gammacell 100 and 200. Each has a fixed ring of encapsulated Cobalt-60 rods, surrounded by a lead shield, into which the specimen is moved. Operation is by electric motor and timer. The specimen is placed in the sample chamber which is lowered into the ring of Cobalt-60 rods and withdrawn at a pre-set time.

Aircraft fuel gauge

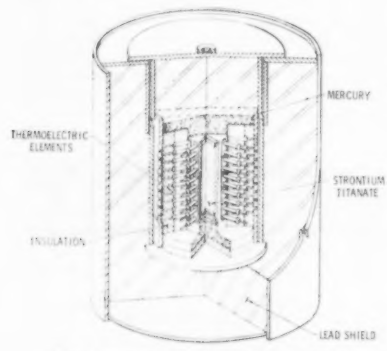
A transistorized radiation gauge which measures fuel in aircraft with greater accuracy than conventional devices has been developed, claims Atomics International, a division of North American Aviation. The lightweight gauge consists of radioisotopes and detector units mounted outside the fuel tanks. Gamma rays pass through the tanks and the intensity of the rays reaching the detectors indicates the amount of fuel.

Amersham's Carbon-14 range

The Radiochemical Centre, Amersham, now offers a wide range of carbohydrates labelled with Carbon-14, eleven specifically and ten with uniform labelling. D-Glucose labelled with tritium is also available, while for metabolite studies and other tracer investigations, the Centre offers a range of steroids and steroid hormones, 11 being labelled with Carbon-14 and eight with tritium.

Isotope weather station

The Martin Company's radioisotope-powered automatic weather station (See *Isotope Review*, August, p 92) is to be located in the Canadian Arctic. It is designed for radio transmission of wind direction and speed, temperature and barometric pressure every three hours to two receiving stations.



The isotope-fuelled weather station

The design characteristics are as follows:

FUEL: 17,500 curies of strontium-90 in the form of strontium titanate pellets.

FUEL ELEMENTS: 5 in high, 2·1 in in diameter.

FUEL CONTAINMENT: three layers 0·250 in thick Hastelloy C.

SHIELD: lead, 4·4 in thick.

THERMOCOUPLES: 60 pairs, 1½ by 3/16 in diameter.

OUTPUT: 5 watts at 4·0 volts dc converted to 28 volts dc to supply trickle charge to nickel-cadmium batteries.

WEIGHT: 55 lbs plus 1625 lbs of shielding.

OPERATING LIFE: minimum two years without refuelling or servicing.

Blood activation analysis

The application of activation analysis could lead to longer life for blood stored in 'blood banks,' members of the American Medical Association were told at a recent New York Scientific Exhibition. Dr William Bethard, medical director of General Dynamics Corporation's General Atomic Division, described results obtained with a TRIGA research reactor in detecting trace elements in whole blood cells. Through the controlled exposure of a specimen of whole blood in the reactor, measurements of most elements in parts per million and in some instance, in parts per 1000 million, were possible.

Modified Pu-Be sources Plans to modify its standard Pu-Be neutron sources have been submitted to the USAEC by the Nuclear Materials and Equipment Corporation of Pennsylvania. The company is planning to use tantalum inner container blanks formed from sheets prepared by powder metallurgy. These would be machined after full vacuum annealing. Such a method of fabrication could be carried out with some saving in costs compared with the use of arc-cast tantalum, the company claims, while the strength of the containers should be greater due to relatively small grain sizes that result from annealing.

NEWS ROUND-UP

AEA stockpiles Cobalt-60

To meet the expected demand for large quantities of Cobalt-60 for industrial irradiation processes, the UKAEA has built up a stock of about two million curies of this isotope, the Authority's annual report points out. During 1960-61 alone, about 500,000 curies were processed and delivered to industrial and experimental installations. Demand for labelled compounds and radiation sources rose during the year and the total value of sales was up by 10% to over £1·3 million. The proportion exported remained at about 60% with the number of consignments despatched being 40,000.

India expands facilities

Work has started in India on a new laboratory designed for handling the much larger amounts of radioisotopes which will be produced in the CIR facility. A new section, which will synthesise labelled compounds, has been set up and produced its first samples of organic compounds marked with Carbon-14, says the Indian AEC's annual report. Work has also started on a new laboratory for handling bulk amounts of radioactivity. However, the report points out that while shortage of radioisotopes is no longer a problem, their use in India is hampered by lack of trained personnel. Measures are being taken to remedy this deficiency.

Surplus Co-60 says Canada

On a world basis, there is at present a surplus capacity for the production of Cobalt-60 and the price of low specific activity material has fallen, says Atomic Energy of Canada Ltd's annual report. Canadian production has been concentrated on high specific activity cobalt as required principally for the beam therapy programme. By the end of the year, 235 therapy machines had been sold or delivered to 37 countries while 26 Gammacell-220 models are in service in 12 countries. During the year, the Commercial Products Division of AECL shipped its millionth curie of radioactive material, making Canada the first country in the world to reach this total.

Body counting Methods of measuring the total amount of radioactivity in the body of a living person were reviewed at an International Atomic Energy Agency symposium held in Vienna recently. About 130 scientists from 26 countries attended this meeting on Whole Body Counting. It followed another meeting on the effects of ionising radiation on the nervous system.

US—Czech exports The USAEC has approved the export of 25 millicuries of Carbon-14 and 100 millicuries of tritium labelled biochemical compounds to the Omnia Foreign Trade Corporation, Prague, Czechoslovakia. The materials will be used for medical and biochemical research purposes.

USEFUL READING

A new tagging technique for measuring slow flow rates and material dwell times, T. C. Gregson and S. D. Gehman, Research Division, The Goodyear Tire & Rubber Co., Akron 16, Ohio, USA.

Development of safety performance tests for radioisotope sealed sources and devices, paper presented at Health Physics Society meeting, Las Vegas, June 13, 1961, by James Hitch USAEC Office of Isotopes Development (OID). Dr Paul Aebersold, Director OID, collaborated in the preparation of this paper.

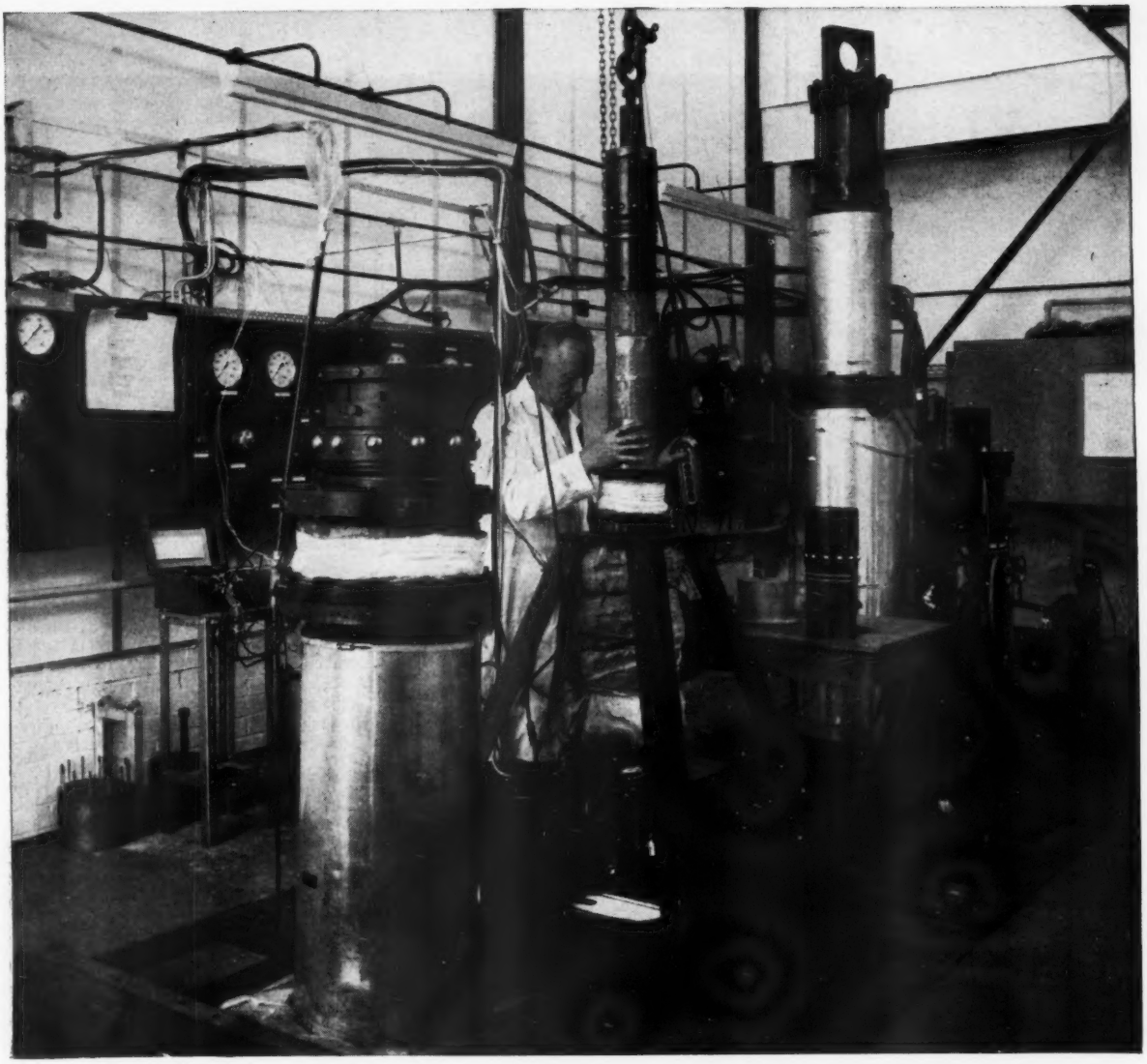
Bibliography on Industrial Radiology, Vol. VIII, 1958-60, by Herbert R. Isenberger, price $4.00 from St John X-Ray Laboratory, Califon, New Jersey, USA.

Gamma irradiation in Canada, 50 pp., a collection of papers on Canadian work in this field. A limited number of copies available from Atomic Energy of Canada's UK representative, Watson & Sons (Electro-Medical) Ltd, Industrial Division, East Lane, North Wembley, Middlesex, or from *Nuclear Power*.

Isotope Catalogue (in German) published by Technocommerz GmbH, Rosenthaler Strasse 40/41, Berlin C2, German Democratic Republic.

Labeled nucleosides, issued by New England Nuclear Corp., 575 Albany Street, Boston 18, Mass, USA.

C-14 Labeled radiochemicals, issued by Research Specialities Co., 200 South Gerrard Blvd., Richmond, California, USA. An enlarged and revised edition is to be issued shortly.



F.R. standpipe closures

advanced design backed by unrivalled test facilities

Adopted by major nuclear design groups, F.R. Standpipe Closures—prototypes of which are seen here under test—are the result of unrivalled design experience and test facilities in the nuclear field. Simple and foolproof, Standpipe Closures seal off the standpipes of reactors under load. They are suitable for top, bottom or side mounting in any radial position, and can be positioned or removed by a straight forward lower or lift. A pressure lock prevents the closure being removed until pressures above and below are equalised. Provision can be made for fitting control rod motors, flux scanning heads or hand winding drives which can be incorporated above, below or within the closure. Production versions of the F.R. Standpipe Closure are designed for most fluids at pressures up to 700 p.s.i. (49.21 kg/om²) and temperatures up to 150°C. but development for higher duties is continuing.

Now on order for 5 nuclear power stations

Berkeley (A.E.I.—J.T.)
Hinkley Point (E.E.)
Latina (N.P.P.C.)
Trawsfynydd (A.P.C.)
A.G.R. at Windscale (U.K.A.E.A.)

F.R. *services to the Nuclear Industry*

Flight Refuelling Ltd TARRANT RUSHTON AIRFIELD · BLANDFORD · DORSET · TELEPHONE: BLANDFORD 501

BUSINESS NEWS

GEC ORDERS RISE Orders received by the **General Electric Company** in the year to March 31, 1961, increased from £118,755,000 to £127,891,000. However, the net profit fell by £1,554,000 compared with the previous year. A figure of £11,236,396 is given in the accounts for bank overdrafts. The report says that a major issue still under discussion at the close of the year was the financial settlement with regard to Hunterston nuclear power station contract. The directors believe the provisions already made are adequate. The profit returned by the Engineering Group has been very disappointing, the report continues. There is world-wide surplus capacity for production of heavy engineering equipment and there is consequently intense competition both at home and overseas. This situation is likely to continue until world demand for these products improves.

DRAGON INSTRUMENTATION **Automatic Control Engineering Ltd** is to design, supply and install the instrumentation for the High Temperature Gas-Cooled Reactor being built at the AEE, Winfrith (DRAGON project). The contract from the AEA provides for the purchase of all instruments and similar equipment by competitive tendering among firms in signatory countries to the Dragon project. A data logging system for recording approximately 900 variables and having facilities for pre-set alarm levels and digital display will be incorporated in the instrumentation system. The contract is due for completion by December, 1962.

FLEXIBOX EXPAND **Flexibox Ltd,** Manchester, have formed two new subsidiaries in Italy and Australia—**Flexibox S.p.A.** and **Flexibox Pty. Ltd.** The Flexibox range includes mechanical seals for pumps, compressors, mixers and other rotary equipment and precision lapping machines. The new Australian subsidiary will be jointly owned by Flexibox and **Harland Engineering (Australia) Pty. Ltd** of Victoria. Flexibox also have Dutch, French and German companies in their group.

SOLARTRON AGREEMENT **Solartron Laboratory Instruments Ltd** has granted **Packard Bell Electronics Corporation** a licence to manufacture the Solartron CD 1014 portable double beam oscilloscope and the CD 1016, the rack mounted version of this instrument, in the USA. Packard Bell have placed an initial order for 200 CD 1014 instruments to meet immediate sales needs while they develop full scale production to meet a forecast of 6000 CD 1014 instruments per year. The agreement not only covers full manufacturing know-how but also includes a visit by the Production Director of Solartron Laboratory Instruments, Mr T. Daly, who will pass on practical experience in manufacture of these instruments.

NEW WINDSCALE ORDERS An order for the supply and commissioning of remote handling equipment to be installed in the decanning and decontamination caves at Windscale, Cumberland, has been placed with the **General Electric Company** by the UKAEA. It is to be used for handling the irradiated fuel elements of the Authority's nuclear stations and also for the first of the CEGB nuclear stations. Commissioning is scheduled for the spring, 1962.

Another Windscale order, this time for four **Tannoy** systems, has now been completed. The systems were installed to give early warning of faults and have a total output of near one kW. They are complete with transistorised coded warning oscillator.

• **Dewrance & Co. Ltd** have just secured a contract for the complete heat exchanger mountings and steam and feed pipeline valves needed for the 580MW Sizewell station being built for the CEGB by the **English Electric, Babcock & Wilcox, Taylor Woodrow Atomic Power Group.**

OVERSEAS

NEW RESEARCH LABORATORIES The Swedish steel firm **Sandvik,** who spend around £1 million annually on research—3·5% of the company's turnover—has recently opened new laboratories for the development of stainless steels, particularly for reactor use. More than 65,000 ft of high-grade stainless steel tubes are being supplied for use in the heat exchangers of Sweden's first power reactor, the 70MW R3/ADAM, now under construction near Stockholm. Radioactive tracers are used during the manufacturing stage to prevent the confusion of materials. Every finished tube is inspected ultrasonically.

SWISS REACTOR CONTRACT The **Babcock & Wilcox Company** of the US is to supply twenty 90% U-235 enriched fuel elements for the University of Basel reactor Switzerland. The elements will be delivered early this autumn. The reactor itself, designed by Aerojet General Nucleonics, is scheduled to go into operation at the end of 1961.

SPECTRAL SHIFT REACTOR A $211,000 contract has been awarded to the **Babcock & Wilcox Company** by the AEC for a plant analysis study of its heavy-light water moderated reactor, known as the Spectral Shift Control Reactor. B. & W. will make an economic analysis of the reactor system and also study areas of system improvement and establish other criteria required for actual plant construction. Under a $1,223,500 AEC contract awarded last year, successful physics studies have established that reactor control can be accomplished by using varying mixtures of heavy and light water, thereby making it possible to operate with control rods out of the reactor at full power.

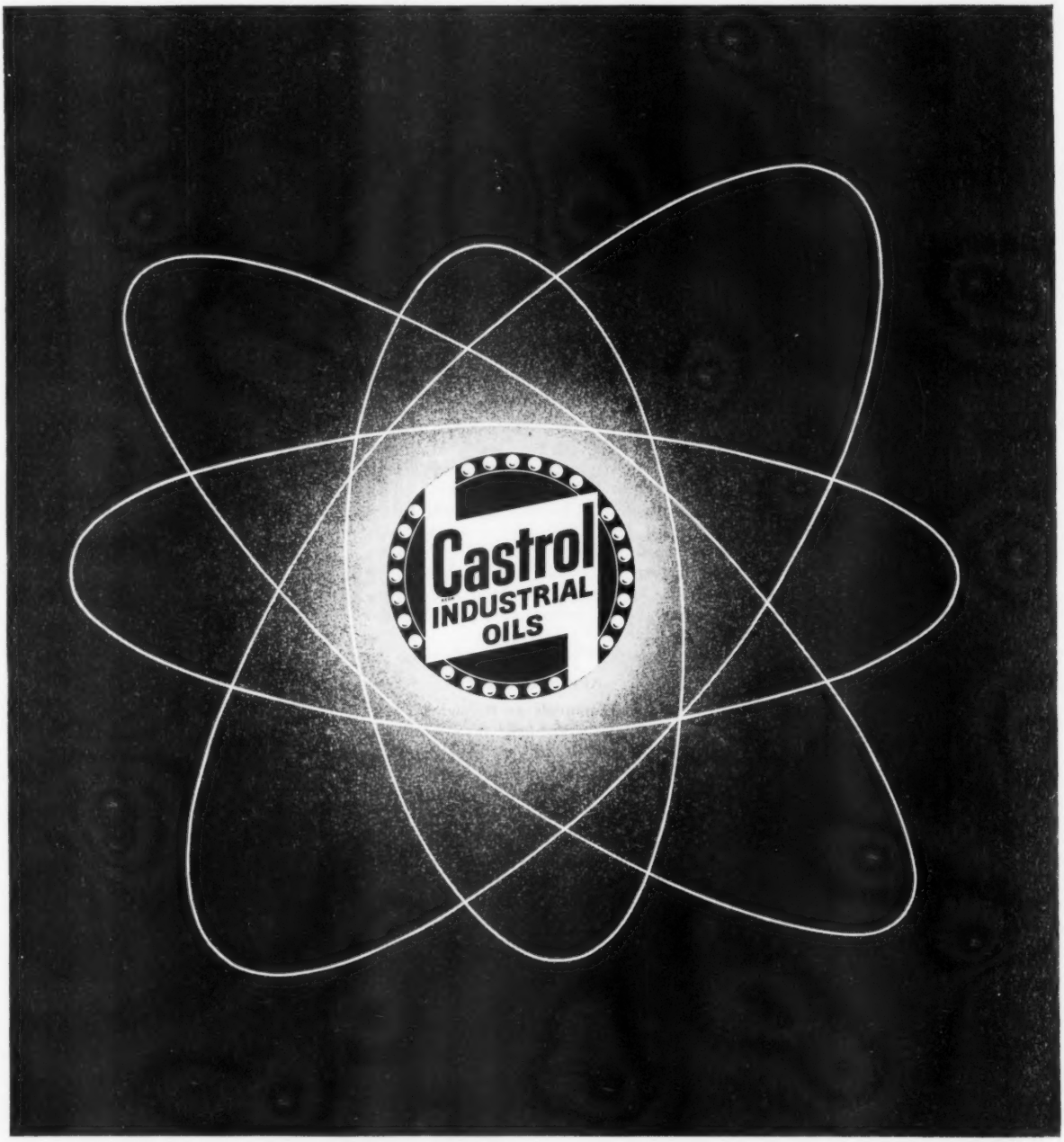
• The **French Atomic Energy Commission** has ordered from **Compagnie Européenne d'Automatisme Electronique** a system for automatic digital analysis of measurements for the test model of RAPSODIE, a fast research reactor which is to be installed at Cadarache.

• A special electronic microscope, a Metioscope, which will make possible direct observation of metal surfaced at temperatures of up to 1000°C, has been supplied to Euratom's Ispra centre by the Swiss firm, **Trueb Taueber AG.**

• **Pechiney** of France is to deliver 4500 tons of nuclear grade graphite to **Electricite de France** for the EDF-3 reactor. Deliveries will be completed in August, 1963.

• A joint five state collecting centre for radioactive waste is to be established at Geestacht-Tesperhude, W. Germany.

PARSON'S LABORATORY Mr J. L. Gray, Turbine Plant Design Engineer, CEGB, in the new Mechanical Research Laboratory he recently opened for C. A. Parsons & Co. Ltd. The group includes Dr A. T. Bowden, chief research engineer, Mr J. L. Jefferson, manager, mechanical research department and Mr Gordon Baker, managing director



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J. L. THOMPSON
Managing director

People

by John Radford

F. W. STOKES
Powell Duffryn

Recent changes at Square D Limited include that of **Mr J. L. Thompson** as managing director. He had been general manager of the company since its inception in November, 1955, and was appointed to the board in 1958. Other changes include the appointment of **Mr D. Gemmell** as general manager of the company's Swindon establishment and **Mr R. G. Camp** as executive director. Mr Gemmell was previously executive director and Mr Camp, sales manager.

The new US Atomic Energy Commission's scientific representative in London is **Dr M. Carl Walske,** who has been serving since November, 1959, with the US delegation to the Geneva Conference on Discontinuance of Nuclear Weapons Tests. He was previously deputy research director of Atomics International and also a vice-president of Hazelton Nuclear Science Corporation, California.

Directors have been appointed to three divisions of the International Atomic Energy Agency. They are: **Dennis Wiffon Pearce** (USA) to head the Division of Health, Safety and Waste Disposal; **Carlos Sanchez del Rio** (Spain) to head the Division of Reactors and **Costmir Simano** (Czechoslovakia) to head the Division of Technical Supplies. Other IAEA appointments include that of **Dr Raja Ramanna** of India as chairman of the management committee which will determine the joint research programme in reactor physics using Norway's zero power reactor NORA and **Dr Pierre Louis Balligrand** of France and **Dr Carlo Salvetti** of Italy as committee members.

Mr Bernard Feltbower (49) who joined the English Electric Company at the beginning of July has been appointed chief engineer of the company's Control Gear Division at Kidsgrove, Stoke-on-Trent. He will be responsible for all the technical administration and new projects of the division at Kidsgrove which specialises in all aspects of electric motor control and the engineering of automatic control schemes for industrial processes. Mr Feltbower was born in Vienna and was previously general manager and chief engineer of Electro Dynamic Construction Co Ltd's control gear division.

After eleven years with Powell Duffryn Carbon Products Ltd, **Mr F. W. Stokes** (46) has been appointed managing director. He came to Powell Duffryn as works manager in 1950, was appointed to the board nine years later and was made general manager in February, 1960. Before joining his present firm, Mr Stokes was with the Birmingham Small Arms Company Ltd, specialising in production engineering.

APPOINTMENTS

K. R. Simmonds as managing director of International Rectifier Company (Great Britain) Ltd., a company owned jointly by Metal Industries Ltd. and the International Rectifier Corporation of Los Angeles.

T. K. Jenkins as manager of the Diamond Drilling Division, Coventry Compressors Ltd, hirers of contractors plant.

Dr A. W. Henderson as chief chemist/metallurgist, The Plessey Company Ltd.

R. J. F. Howard as director of marketing, Metal Industries Ltd. He is responsible for co-ordination of marketing activities of the electrical companies within the M.I. group.

D. N. Steed to the main board of Teddington Aircraft Controls Ltd as works director.

F. R. Allen, executive director of Firth Cleveland Instruments Ltd, as head of the company's Sales Engineering Department.

J. M. Baldock, former MP for Harborough, to the board of CIBA United Kingdom Ltd.

Anthony M. Browne as president of the British Electrical and Allied Manufacturers' Association. Mr Browne is chairman and managing director of Hackbridge and Hewittic Electric Co. Ltd.

Prof. J. A. Goedkoop as managing director for research of Reactor Centrum Nederland. Prof. Goedkoop was the head of the physics department.

Dr Dragoslav Popovic of Yugoslavia as Director of the IAEA's Safeguards Division.

C. H. Davy, resident director of Babock & Wilcox Ltd's Scottish works since 1951, has returned to London head office as an executive director.

Mr Stanley H. Goss as joint managing director, with **Mr L. G. Oxford,** of Firth Cleveland Instruments Ltd, Glamorgan.

Mr J. P. V. Woollam as deputy chairman of Simon-Carves Ltd. He is also a director of Simon Engineering Ltd.

Mr K. A. Robinson (34) to the board of Lancashire Dynamo Electronic Products, a company in the Metal Industries Group.

Academician **Mstislav Keldysh** (50), a prominent mathematician, mechanical engineer and computer expert, has been elected president of the USSR Academy of Sciences.

GEC VISIT Professor H. Uchida (second left), a member of the Japanese Atomic Energy Commission's Safety Committee examining the manometer system forming part of a scale model of the Tokai reactor pressure vessel during a recent visit to the GEC's laboratories. Others in the picture are (l to r) Dr R. Skipper, Mr S. Wearne (GEC) and Mr Y. Imai, Japan Atomic Power Company

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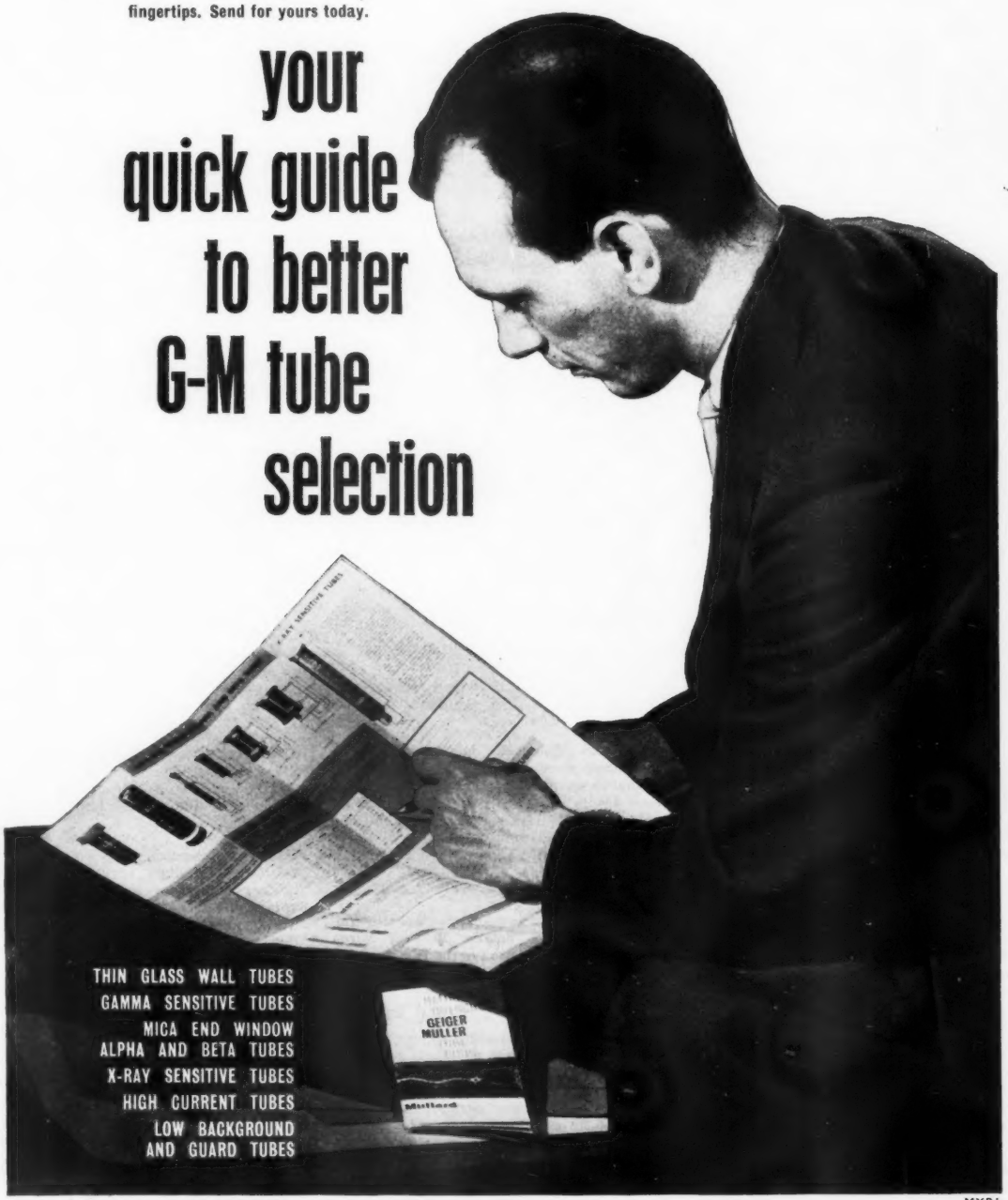

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MICA END WINDOW ALPHA AND BETA TUBES
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MXR1

Diary

30 AUGUST–6 SEPTEMBER
British Association for the Advancement of Science, 123rd meeting, Norwich. Details, Secretary, BAAS, 18 Adam Street, London, WC2

5–8 SEPTEMBER
National conference, **engineering inspection and non-destructive testing,** Oxford. Details, Institution of Engineering Inspection, 616 Grand Buildings, Trafalgar Square, London, WC2
Conference, **machine translation of languages** and applied language analysis, National Physical Laboratory, Teddington, Middlesex, to whom inquiries should be addressed

4–8 SEPTEMBER
Rutherford international conference on **low energy physics,** Manchester. Organized by the International Union of Pure and Applied Physics. Details, Dr L. J. B. Goldfarb, Physics Dept., Manchester University, Manchester, 13

6–8 SEPTEMBER
Conference, **microwave measurements techniques,** London. Also exhibition of microwave measurement techniques. Details, Institution of Electrical Engineers, Savoy Place, London, WC2

6–16 SEPTEMBER
Annual conference, International Federation for **Documentation,** London. Details, ASLIB, 3 Belgrave Square, London SW1

9–11 SEPTEMBER
Conference, Royal Statistical Society, University of Bristol. Details, Mrs P. Aratie, Dept. of Operational Research and Cybernetics, United Steel Companies, 1 Tapton House Road, Sheffield, 10

11–12 SEPTEMBER
Symposium on **nuclear instruments,** Harwell. Details, Dr L. J. B. Goldfarb, Physics Dept., The University, Manchester, 13

12-15 SEPTEMBER
Mass spectrometry, Oxford University. Organized by Institute of Petroleum and American Society for Testing Materials. Details, W. J. Brown, Instrumentation Division, AEI (Manchester) Ltd, Trafford Park, Manchester 17

13–15 SEPTEMBER
Photomultiplier tube applications, symposium, London. Details, EMI Electronics Ltd, Valve Division, Hayes, Middlesex

20–22 SEPTEMBER
Symposium 'Some aspects of the **physics of space research**', Royal Military College of Science, Shrivenham, Swindon, Wiltshire. Details, administration assistant, The Institute of Physics, 47 Belgrave Square, London, SW1

21-23 SEPTEMBER
Industrial radiology today, Blossoms Hotel, Chester. Meeting organized by the Non-Destructive Testing Society of Great Britain

21–22 SEPTEMBER
Conference, **radiospectroscopy of solids,** University College of North Wales, Bangor. Details, administration assistant, Institute of Physics, 47 Belgrave Square, London, SW1

26 SEPTEMBER–6 OCTOBER
Heating, Ventilation and Air Conditioning exhibition, Olympia, London

27 SEPTEMBER–4 OCTOBER
International conference on **heating, ventilating and air conditioning,** London. Details, conference secretariat, Institution of Heating and Ventilating Engineers, 49 Cadogan Square, London, SW1

28–29 SEPTEMBER
Conference, **'The Physics of gas discharge devices,'** Town Hall, Leamington Spa. Details, administration assistant, Institute of Physics, 47 Belgrave Square, London, SW1

28-29 SEPTEMBER
Symposium on **oxidation processes in chemical manufacture, London.** Details, Hon. Sec., Society of Chemical Industry, 14 Belgrave Square, London SW1

OVERSEAS

21–24 AUGUST
International conference on **photoconductivity,** Ithaca, New York, USA. Details, A. R. Hutson, Bell Telephone Laboratories, Murray Hill, N.J., USA

21–25 AUGUST
Gordon Research conference on **photonuclear reactions,** Meriden, New Hampshire, USA. Details, W. George Parks, Director, Gordon Research Conference, University of Rhode Island, Kingston, R.I., USA

21 AUGUST–2 SEPTEMBER
Tenth Pacific Science Congress, Honolulu. Details, Secretary General, 10th Pacific Science Congress, Bishop Museum, Honolulu 7, Hawaii, USA

23–25 AUGUST
Fourth Biennial **gas dynamics symposium,** Evanston, Illinois, USA. Details, Gas Dynamics Symposium, Mechanical Engineering Dept., Northwestern University, Evanston, Ill., USA

23–26 AUGUST
Eighth international conference of the Institute of Management, Brussels. Details, Max Duval, Office Belge pour l'Accroissment de la Productive, 60 rue de la Concorde, Brussels, Belgium

28–30 AUGUST
Symposium on **university use of sub-critical assemblies,** Gatlinburg, Tennessee, USA. Details, W. W. Grigorieff, University Relations Division, Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee, USA

28 AUGUST–1 SEPTEMBER
International **heat transfer conference,** Boulder, Colorado, USA. Details, S. P. Kezios, c/o American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N.Y., USA
Fifth international conference on **ionization phenomena in gases,** Munich, Germany. Details, H. Pinzek, secretary, Oskar-von-Miller-Ring 18, Munich 1, Germany

3–8 SEPTEMBER
140th meeting of the American Chemical Society, including symposium on **nuclear technology,** Chicago, Illinois, USA. Details, A. T. Windstead, National Meetings Department, American Chemical Society, 1155 Sixteenth Street, N.W., Washington 6 D.C., USA

3–10 SEPTEMBER
Seventh Inter-American congress of **radiology** including session on **nuclear medicine,** Sao Paulo, Brazil. Details, Secretary General, 7th Inter-American Congress of Radiology, 94 Rua Marcom, Sao Paulo, Brazil

3–10 SEPTEMBER
German **welding and cutting** exhibition, Essen. Details, Gemeinnutzige Ausstellungs GmbH, 2 Norbertstrasse, Essen. Germany

4–9 SEPTEMBER
IAEA conference on **plasma physics and controlled nuclear fusion** research, Salsburg, Austria.

4–9 SEPTEMBER
Third international conference of the International Association for Analog Computation, including technical, sessions on **application of analog techniques to nuclear problems,** Belgrade, Yugoslavia. Details, Comite Yougoslavie de l'Electronique, des Telecommunications, de l'Automatisme et de la Technique Nucleaire, Decanska 14/IV, Belgrade, Yugoslavia

Industrial Literature

Suppression filters. Belling & Lee are making, by agreement with the US Filtron Co., a range of interference suppression filters, suitable for operation in the range —55°C to 85°C. A recent brochure tabulates the ranges: ratings from 0·15A to 300A, and up to 18,000V d.c. working. In addition, a supplement to the 1959-60 general catalogue of plugs, sockets and connectors has been issued.

★ **252**

Reinforced plastics. Two new booklets from Turner Bros Asbestos cover the products they supply for moulding and reinforcing plastics. One describes the use of 'Durestos', a resinated asbestos moulding material; the other is concerned with 'Duraglas' glass fibre reinforcements.

★ **253**

Electric cables. To celebrate their Silver Jubilee Pyrotenax has published a booklet which covers the characteristics of, and applications for, their 660V and 440V cables, thermocouples and other products.

★ **254**

Molybdenum disulphide lubrication. Rocol recommend their 'Molytherm' grease for continuous service above 350°F, long periods above 450°F and short periods up to 550°F. Based on a high flash point oil and non-soap thickener, it is resistant to steam and water. Publication 17 outlines certain industrial tests that have been made.

★ **255**

Heat transfer. Four new leaflets from Clayton cover performance details of their wire-wound transfer tubes used in the heat transfer between: water and oil, oil and air, water and gases, and in refrigeration.

★ **256**

Epoxy resins. Two interesting applications of 'Araldite' are described in recent technical notes from CIBA. It has been used to bond together end-on-end 48 in glazed stoneware pipes carrying corrosive chemicals. Another application is for flooring; screeds can be easily made which harden in 24 hours.

★ **257**

Digital computers. EMI's new publication 'Export' gives news about the Emidec computer and other EMI equipment in English, French, German and Spanish.

★ **258**

Concrete anchors. The US Phillips 'Red Head' self-drilling concrete anchor is now available from Universal Installations. A leaflet gives specifications and uses.

★ **259**

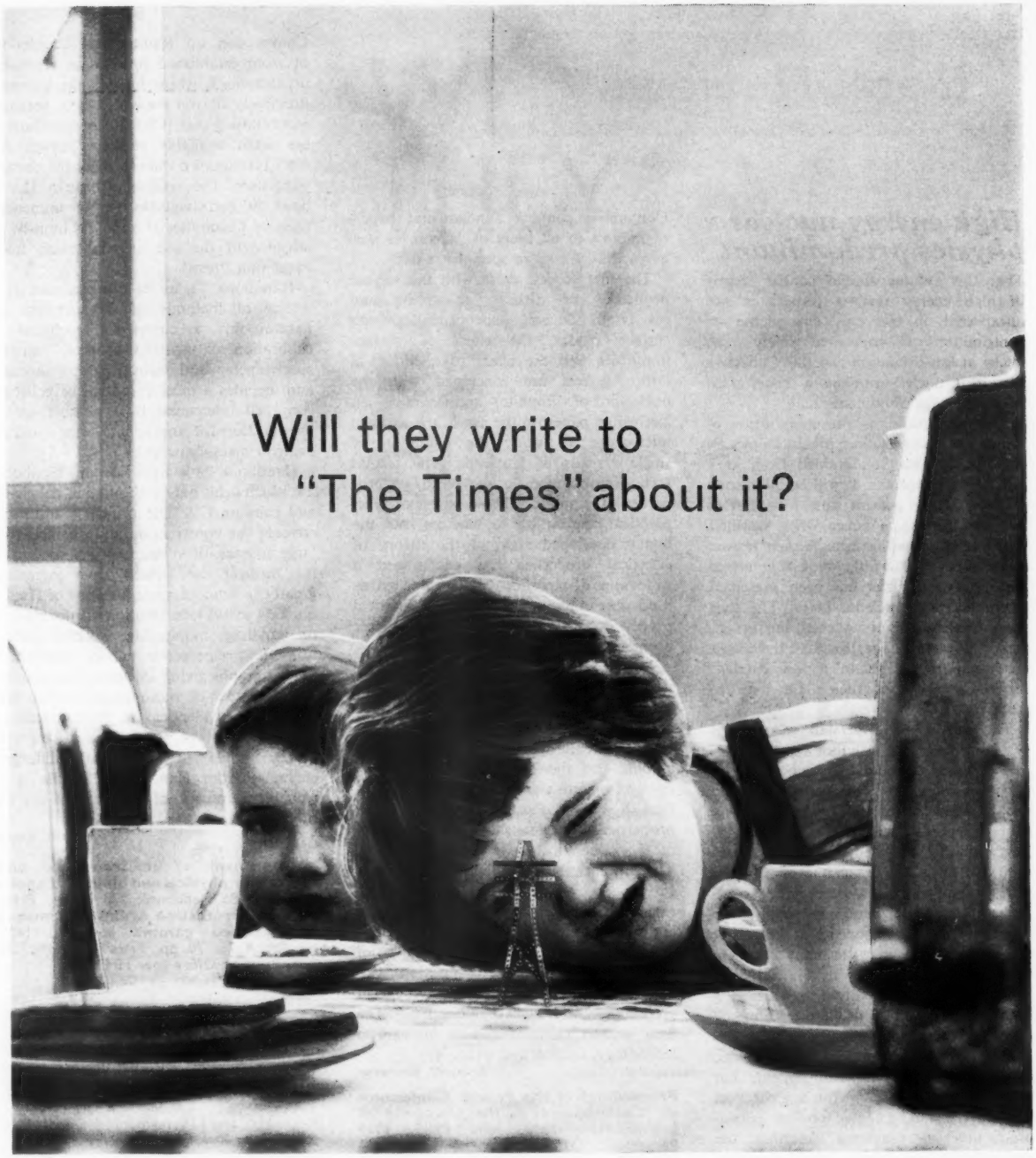
Radiation measuring equipment. The 3rd edition of Philips' abridged catalogue of nuclear equipment has been published. It covers integrated instruments, spectrometers, a portable neutron generator, radiation detectors, monitors, dosimeters, radioactive sources for calibration, and isotopes.

★ **260**

Cable connectors. A recent leaflet from Power Connectors introduces a new range of connectors based on the unit constructional method. The fittings cover single or multi bolt terminals, stem terminals, insulator supported connectors, couplers and tees.

★ **261**

★ *For further information on any item, circle the appropriate number on the reply card facing page* 106



By the time these children are ten years older, Britain's power demands will have doubled. But the number of transmission towers will *not* have doubled. On the contrary — because the Central Electricity Generating Board is adopting 400,000 volt transmission, fewer new towers will be needed. The new power system will use some existing towers, suitably reinforced, and a limited number of new, slightly taller ones. By Act of Parliament, the C.E.G.B. must provide an efficient, economical electricity supply, while preserving visual amenity as far as possible.

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Book Reviews

High energy nuclear physics predominant

That this volume should consist largely of high energy nuclear physics is not unexpected, in fact only one of the six contributions is concerned solely with nuclei at low excitation and this 'Collective motion in nuclei'—presents a theory at an advanced stage of refinement.

The first article, on the composition of primary cosmic radiation, presents a picture of uncertain results obtained from very difficult experiments. It will be interesting to compare the present state with that of two or three years hence when satellite-based experiments have made their impact on the subject. The interaction of polarized nucleons with nuclei has been presented for high energy nucleons only. The style seems unnecessarily complicated and formal, especially when one realizes that the details are of more interest to experimentalists for the analysis of their data than to theorists.

The article on dispersion relations is best described in the editor's own words as 'a survey of the astonishing multitude of conclusions that can be drawn from the innocent assumption that the effect cannot precede the cause'. He should have added 'knowledge of field theory desirable or essential', but even for one not so equipped the greater part is comprehensible. The paper is simply and clearly written. It is hoped that the author can be persuaded to write many others in a similar vein.

The techniques involved in detecting high energy particles using the Cerenkov effect are described; much ingenuity has gone into the design of these systems, chiefly in the optical arrangement, but there seems to be scope for a great deal more. The final chapter on the photo-production of π-mesons describes the experimental state at mid-1959; to someone not working in this field it presents too much, too briefly, and without giving an overall picture.

G. A. Jones

Progress in nuclear physics, volume 8 edited by O. R. Frisch. Pergamon, Oxford and London, 1960. 304pp. Prce 90s.

Wide range of carbon research reported

The series of conferences on carbon which have been held at Buffalo cover a very wide range of interests, both scientific and technological; this report of the 4th Conference contains fundamental papers of interest to all users of carbon, as well as papers of a more specialist nature.

The first section deals with the surface properties of carbon, absorption and reactivity. Several papers dealing with surface oxides, the effect of surface impurities and the effect of quenched-in lattice defects are concerned with the oxidation of graphite, and there is an interesting paper on the use of the electron microscope to study the oxidation of single crystals of graphite. The second section is devoted to the electrical properties of graphite. These have no direct practical application to reactors, but the highly developed state of the theory of electrical properties has encouraged a wide range of experimental work and makes it possible to use measurements of electrical properties as a tool for the study of other problems.

The third section deals with carbonization, graphitization and structure. It includes papers on the relation between crystal growth, structure and properties of both conventional and novel forms of carbon, and there are several papers on electron microscope studies of structure. Part 4 on the mechanical and thermal properties of graphite shows the complexity of the mechanical behaviour of graphite. The still unexplained variation of mechanical properties with temperature continues to be studied and a new set of problems are raised by experiments on the behaviour of graphite under stress in the presence of neutron irradiation. This section also includes papers on the behaviour of graphite at very high temperatures. The final section contains papers on carbon technology, friction and wear.

J. H. W. Simmons

Proceedings of the Fourth Conference on Carbon held at the University of Buffalo New York, June 15-19, 1959 Pergamon, Oxford and London, 1960 778pp. Price £7 10s.

Concise information for health physicists

To those in the Health Physics field, the relevant Handbooks of the National Bureau of Standards are much sought-after, but are not well-known generally. This is unfortunate, since they contain a vast amount of information in concise form. It is true that they give the American viewpoint, but this is of minor importance since all the information stems either from the Recommendations of the International Commission on Radiological Protection, or from established practice in reputable organizations, which interchange information freely all over the world. It is, perhaps, worth noting that ICRP Recommendations are often available earlier, through the NBS Handbooks, than through the normal publishers. The reviewer, through Handbook 69, had available the Recommendations of Committee II about 12 months in advance of the official publication from Pergamon Press.

Handbook 72, as its title suggests, is a review of methods of measurement of neutron flux. It covers such subjects as calibration of neutron sources, neutron spectrometry and measuring instruments, and includes a most comprehensive list of over 200 references. It is a most useful introduction for any scientist interested in neutron measurements.

Handbook 73 is a revision of Handbook 54, which dealt only with radium, cobalt-60 and caesium-137. The principal additions concern the construction and operation of large sources, of kilocurie order, especially for medical use, which have increased greatly in number since the issue of Handbook 54 in 1954. In addition to information on handling, monitoring, working conditions and emergency action, there are several graphs giving shielding information for a number of radioisotopes; these are similar, if not identical, to those contained in the Report of Committee III of the ICRP. While of completely different character from Handbook 72, this is a valuable summary of information on its subject.

H. D. Evans

Measurement of neutron flux and spectra for physical and biological applications, NBS Handbook 72. 92 pp. Price 35 cents. **Protection against radiations from sealed gamma sources,** NBS Handbook 73. 70 pp. Price 30 cents. US Gvt. Printing Office (per HMSO).

New books

- *Spectrochemical analysis*: treatise on the d.c. arc analysis of geological and related materials, by L. H. Ahrens and S. R. Taylor. 2nd edition. Addison-Wesley, Reading, Mass; Pergamon, London, 1961 454pp Price £5 5s

★ 276

- *Nuclear sizes* by L. R. B. Elton. Oxford University Press, 1961 115pp Price 15s

★ 277

- *Modern physics for the engineer* edited by L. N. Ridenour and W. A. Nierenberg. McGraw-Hill, New York and London, 1961 383pp Price £3 14s

★ 278

- *Problems of infection, immunity and allergy in acute radiation diseases* by N. N. Klemparskaya *et al* (translated from the Russian). Pergamon, London, 1961 165pp Price £2 10s

★ 279

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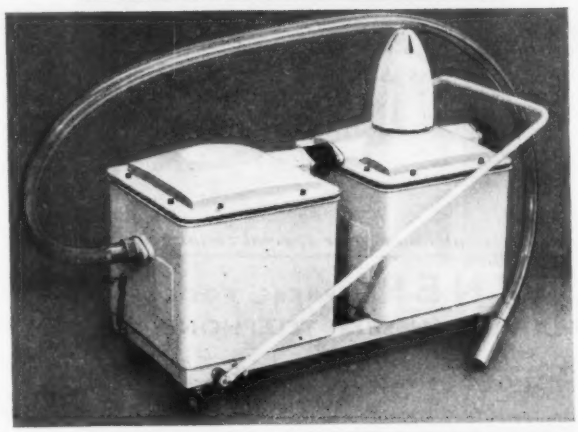

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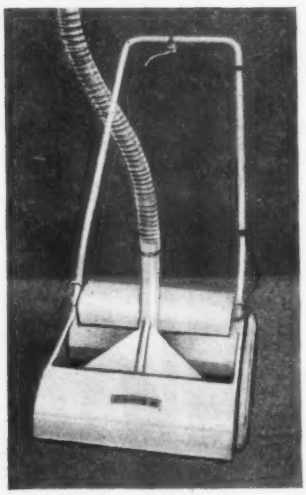

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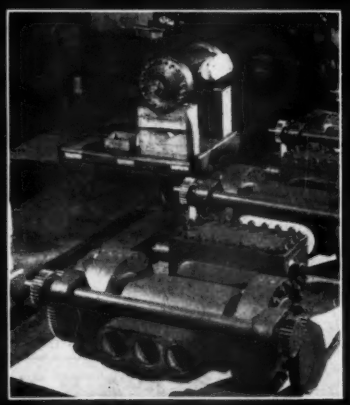

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- Irrigation and water supply equipment
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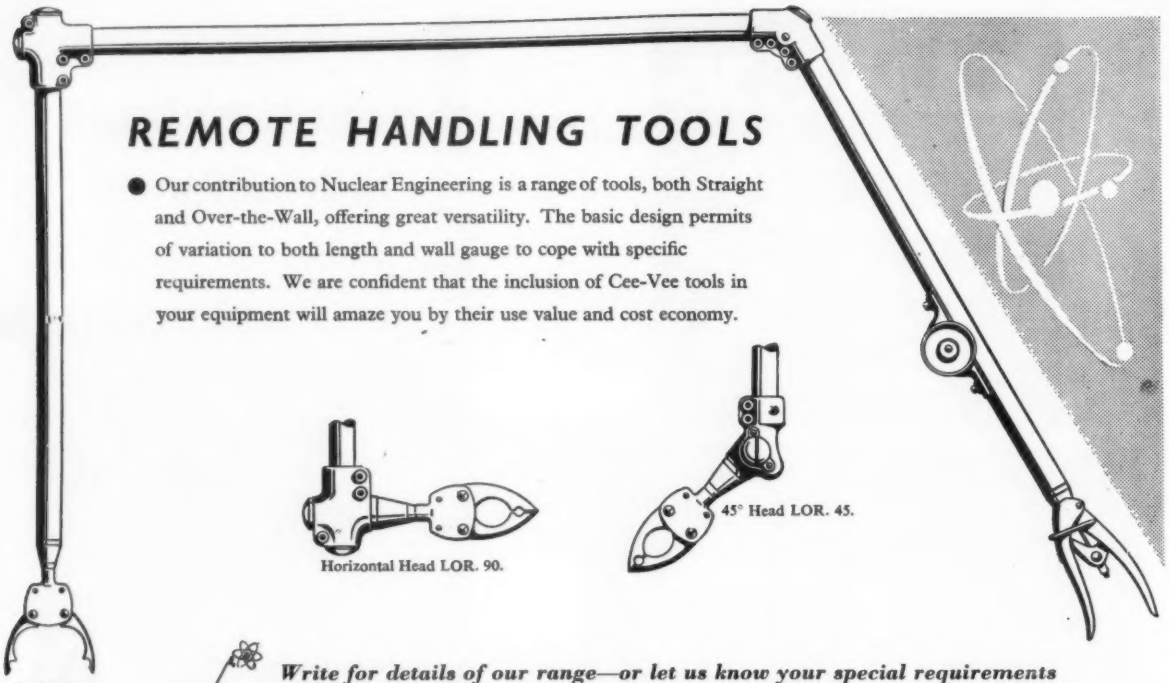

REMOTE HANDLING TOOLS

● Our contribution to Nuclear Engineering is a range of tools, both Straight and Over-the-Wall, offering great versatility. The basic design permits of variation to both length and wall gauge to cope with specific requirements. We are confident that the inclusion of Cee-Vee tools in your equipment will amaze you by their use value and cost economy.

Horizontal Head LOR. 90.

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CARTER & VINER · PRESS TOOL ENGINEERS

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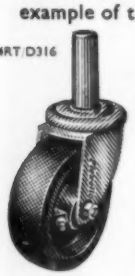
ONE MAN WENT TO MOVE...

Yes, one man is all you need, once you fit Flexello double ball-bearing all steel castors to your trolleys and other equipment. Flexello castors give extra mobility, strength and economy. The series 44 has a stout kingpin adjustable for wear, and a zinc plated rust-proof finish. Available in a variety of wheels and tubular fittings, they are just one example of the vast Flexello range which covers every conceivable aspect of castor mobility.

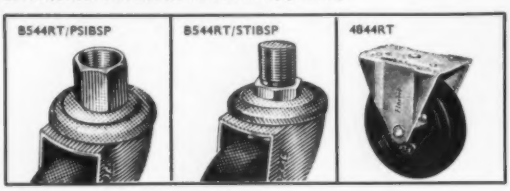
B544RT

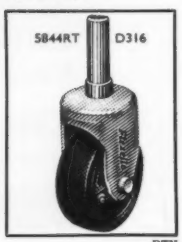
- Rigid embossed steel pressings.
- Substantial king-pin, adjustable for bearing protection.
- Minimum of maintenance.
- Pre-greased hardened bearings.
- Maximum ease of mobility.

S44RT/D316



B544RT/PSIBSP Pipe socket fittings supplied with gas thread for outside fitting.
B544RT/STIBSP Threaded stem and BS male pipe fitting.





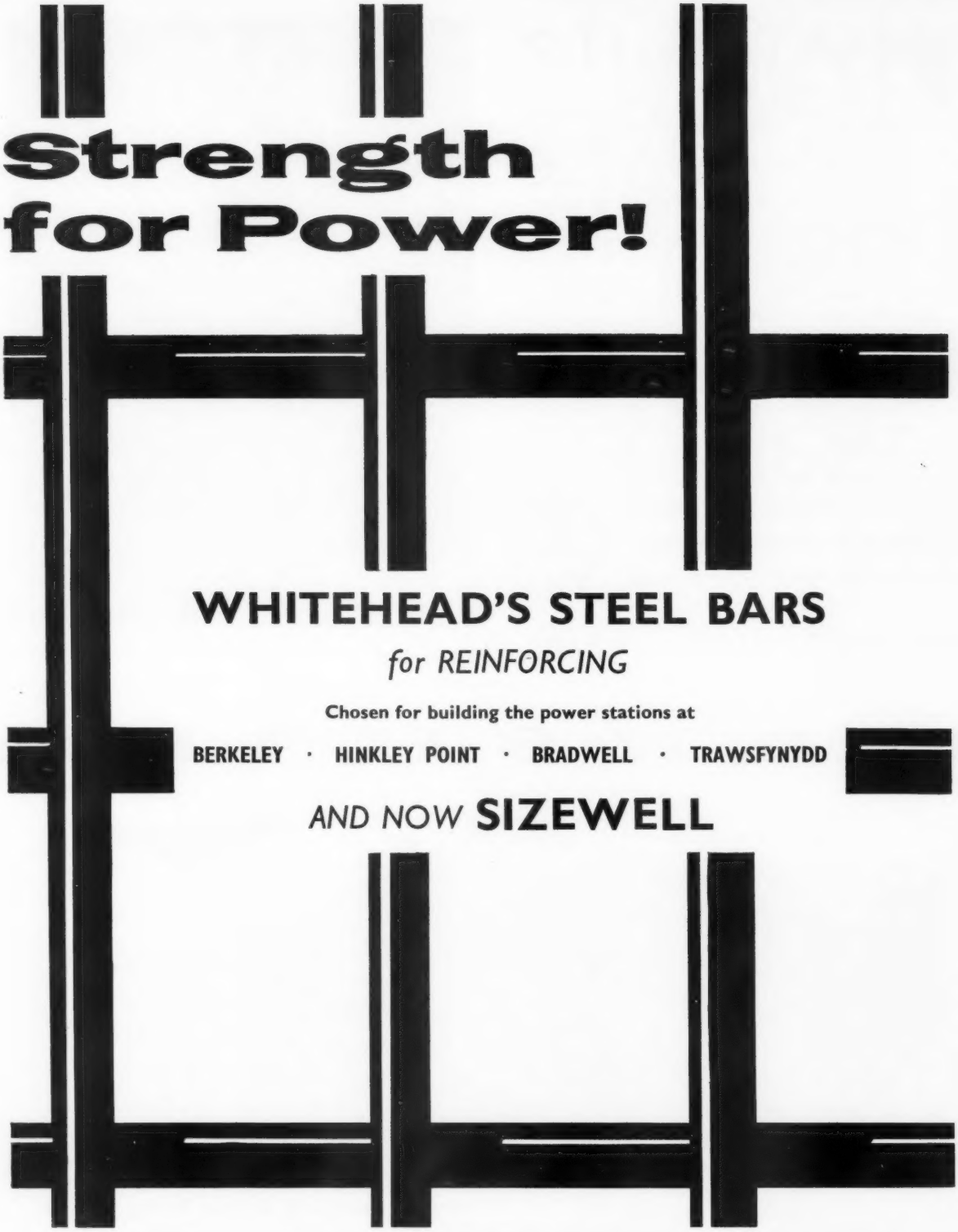
DTV

FIT YOUR EQUIPMENT WITH SERIES 44

Flexello CONSTANT QUALITY CASTORS

Write for comprehensive fully illustrated catalogue to: FLEXELLO CASTORS & WHEELS LTD., SLOUGH, BUCKS.

Strength for Power!



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for REINFORCING

Chosen for building the power stations at

BERKELEY · HINKLEY POINT · BRADWELL · TRAWSFYNYDD

AND NOW **SIZEWELL**

THE WHITEHEAD IRON & STEEL CO LTD

NEWPORT, MON Tel : 65401

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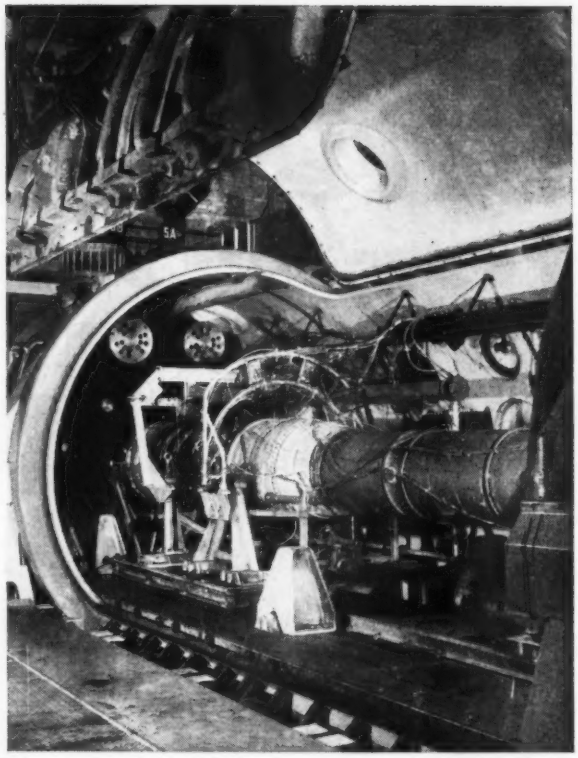
WHAT IS IT?

Our photograph shows a jet engine installed for testing at the Rolls-Royce Altitude Test Plant at Derby. This test cell will be suitable for testing any turbo-jet or turbo-propeller engine envisaged in the next few years. It supplies treated air at the extreme temperature and pressure conditions that aero-engines must withstand. The correct conditions for any selected altitude and forward speed can be achieved in the test cell, and altitudes to at least 70,000 ft. can be simulated. Temperatures can be varied from −90°C. to +190°C.

Subsidiary equipment covers the 11-acre site of the plant, and includes a 750,000 gallon water reservoir from which supplies are drawn for innumerable cooling purposes.

Fire protection equipment for this £6,000,000 plant was engineered by The Walter Kidde Co. Ltd. —sure protection when much is at stake.



Those who have the experience to judge the best buy Kidde

THE WALTER KIDDE COMPANY LTD., Northolt, Middx. Telephone: Viking 6611.

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1 Mc/s SCALER

Type 200

£225

Transistorised
Resolving Time 1 μS
Discriminator Ratio 20: 1
Versatile Paralysis & Internal Timing Circuits

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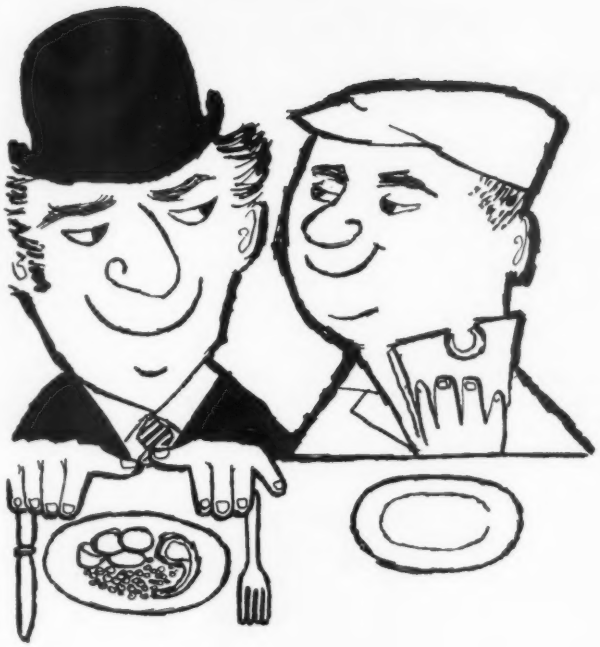
MARSHALL OF CAMBRIDGE ELECTRONICS LIMITED

THE AIRPORT · CAMBRIDGE · ENGLAND



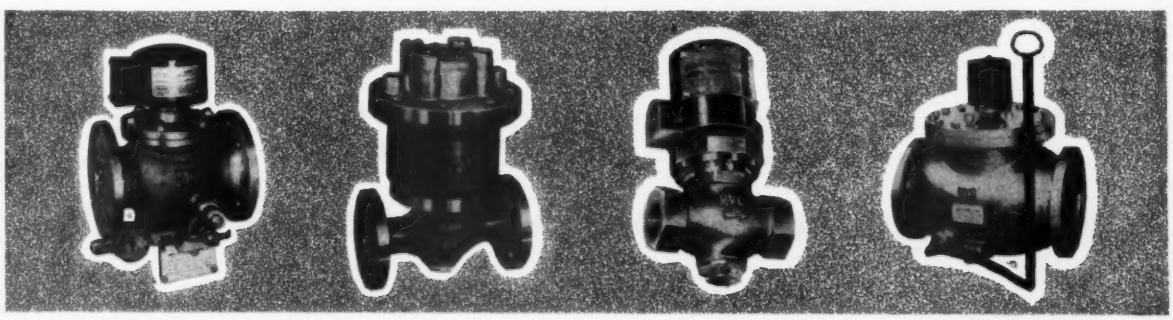
WE OFTEN TALK 'SHOP' AT LUNCH

(Because we like to thoroughly digest our customers problems!).

We like to see a job well done. And we like to see our customers happy! Getting our teeth deeply embedded in to our customers' problems—no matter how specialised and individual—is the backbone of the MVC Service!

Over 30 years' experience and 'know-how' has been built-in to our range of over 100 automatic control valves. People control water with them, gas with them, oil with them, steam with them and a host of other industrial liquids and gases too. Mushrooms are grown with them, jam is made with them and ships' cargoes are frozen with them!

You'll find that expert consultation and advice cost you absolutely nothing at MVC. Our full experience is at your disposal. Many times, what has first appeared to be impossible has been achieved. Why not write **now** for our new comprehensive catalogue No. M124, which contains full details of our complete range!



MVC

The Magnetic Valve Company Ltd

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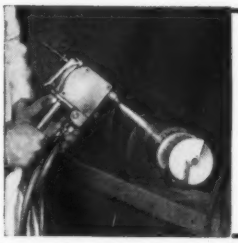
material answer

Sintox, the alumina ceramic of exceptional insulation characteristics, stands elevated temperatures with little change in its properties. Superior in tension, compression and cross-breaking strength, high thermal conductivity and superior corrosion resistance.
For the Nuclear Engineer a new grade of Sintox has been developed. Nuclear Sintox has a low cross-section capture combined with compatibility with most materials used in reactor design. It is versatile in the production of a wide range of shapes and sizes, and particularly suitable for insulating parts in control gear, and mechanical support members.

to design problems . . .



Lodge have developed an alumina spraying process, giving thermal and erosion protection. Special leaflet on request.

SINTOX A PRODUCT OF LODGE

precision engineering ceramics

Sintox Technical Advisory Service. Freely available without obligation. Please write for booklet.

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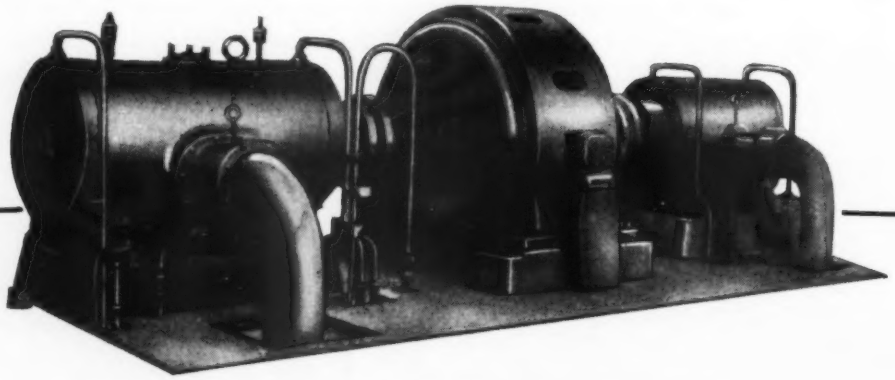

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SUPPLIED FOR: **HARWELL, WINFRITH, BERKELEY**

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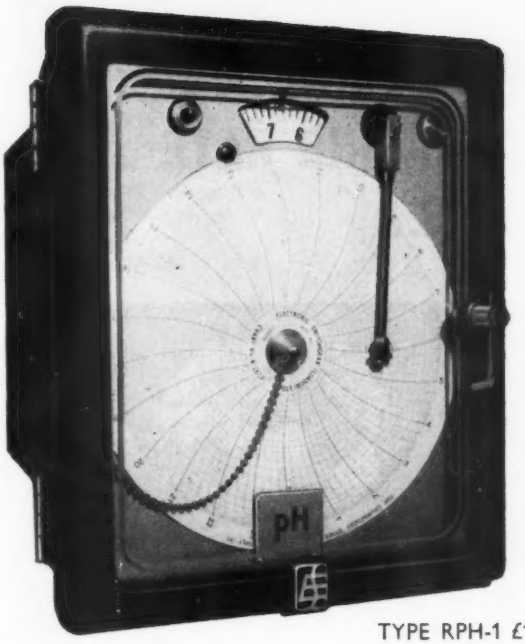

TYPE RPH-1 £188

The 3 in 1 pH SYSTEM

MEASUREMENT • RECORDING • CONTROLLING

are performed by a single instrument connected to a suitably selected pH electrode system.

The System

- **REPLACES costly composite instrument systems**
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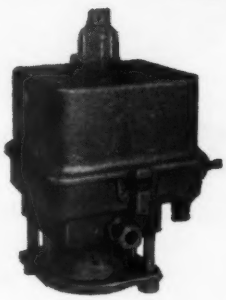
Industrial Electrochemical Instruments



HPF/T electrode system

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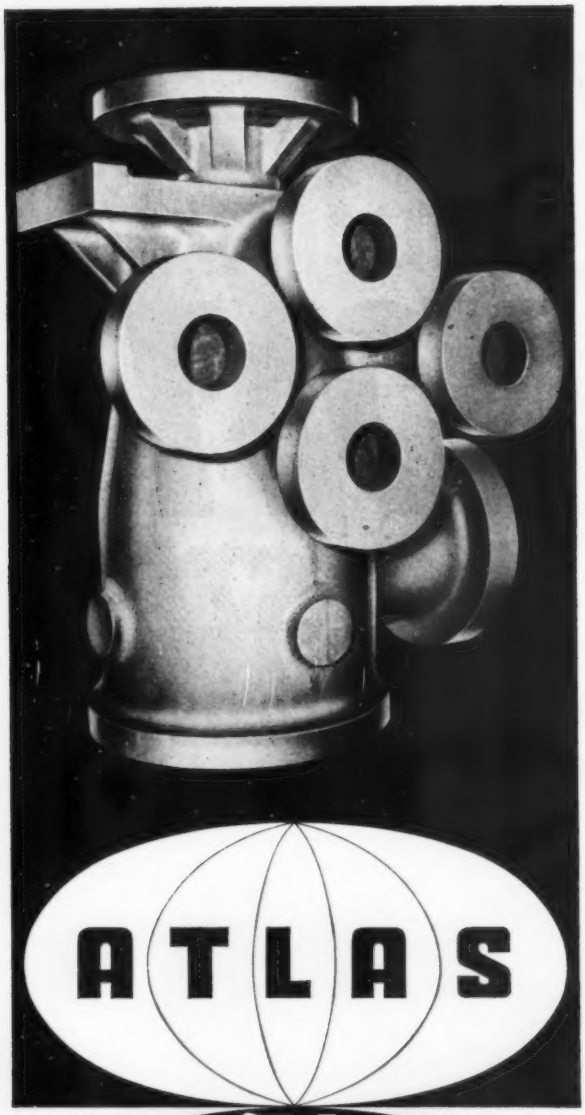

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Turbine Casings, Steam Chests, Valves, etc., in carbon and alloy steels up to 15 tons weight and to any specification.
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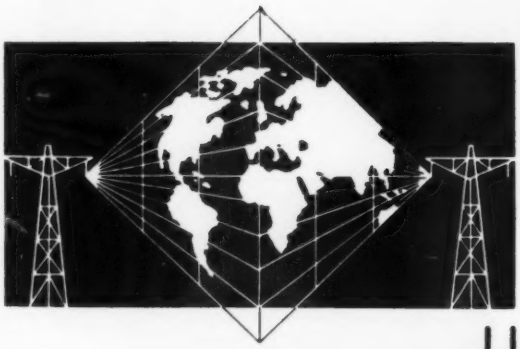
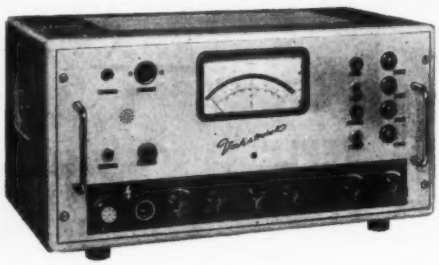


Model VA-D-41 is one of a very wide range of this type of equipment which we are able to supply. Please advise us your requirements, or ask for fully illustrated literature.



Specifications:

Ranges	180—600,000 cpm divided into 8 ranges
Resolving Time in all Ranges	10 μsec
Error of Indication ..	±2%
Integration Time 5 selectable settings providing statistical errors of	1, 2, 4, 8 and 15%
Counting Tube Voltage ..	400—2,000 volts coarse and fine control
Regulation	±0.2% at ±10% mains voltage fluctuations
Connections Provided for..	Pulse Scaler/Recording Meter/Matching Cathode Follower

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在廣告上以有限的地方來解釋一些專門技術及它們的用果的確是有受限制的困難若請貴公司在本雜誌內選一些詳細的情形就請將可買的表格取一張下來將閣下有疑問的項目用笔勾一下郵寄給子能工好者即可.

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廣告紙面の関係上製品の技術的細目は掲載しきれませんので詳しくは裏のカードの適當なナンバーに印をつけて原子力究投函して下さればお答へします.

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7	30	53	76	99	122	145	168	191
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16	39	62	85	108	131	154	177	200
17	40	63	86	109	132	155	178	201
18	41	64	87	110	133	156	179	202
19	42	65	88	111	134	157	180	203
20	43	66	89	112	135	158	181	204
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6	29	52	75	98	121	144	167	190
7	30	53	76	99	122	145	168	191
8	31	54	77	100	123	146	169	192
9	32	55	78	101	124	147	170	193
10	33	56	79	102	125	148	171	194
11	34	57	80	103	126	149	172	195
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16	39	62	85	108	131	154	177	200
17	40	63	86	109	132	155	178	201
18	41	64	87	110	133	156	179	202
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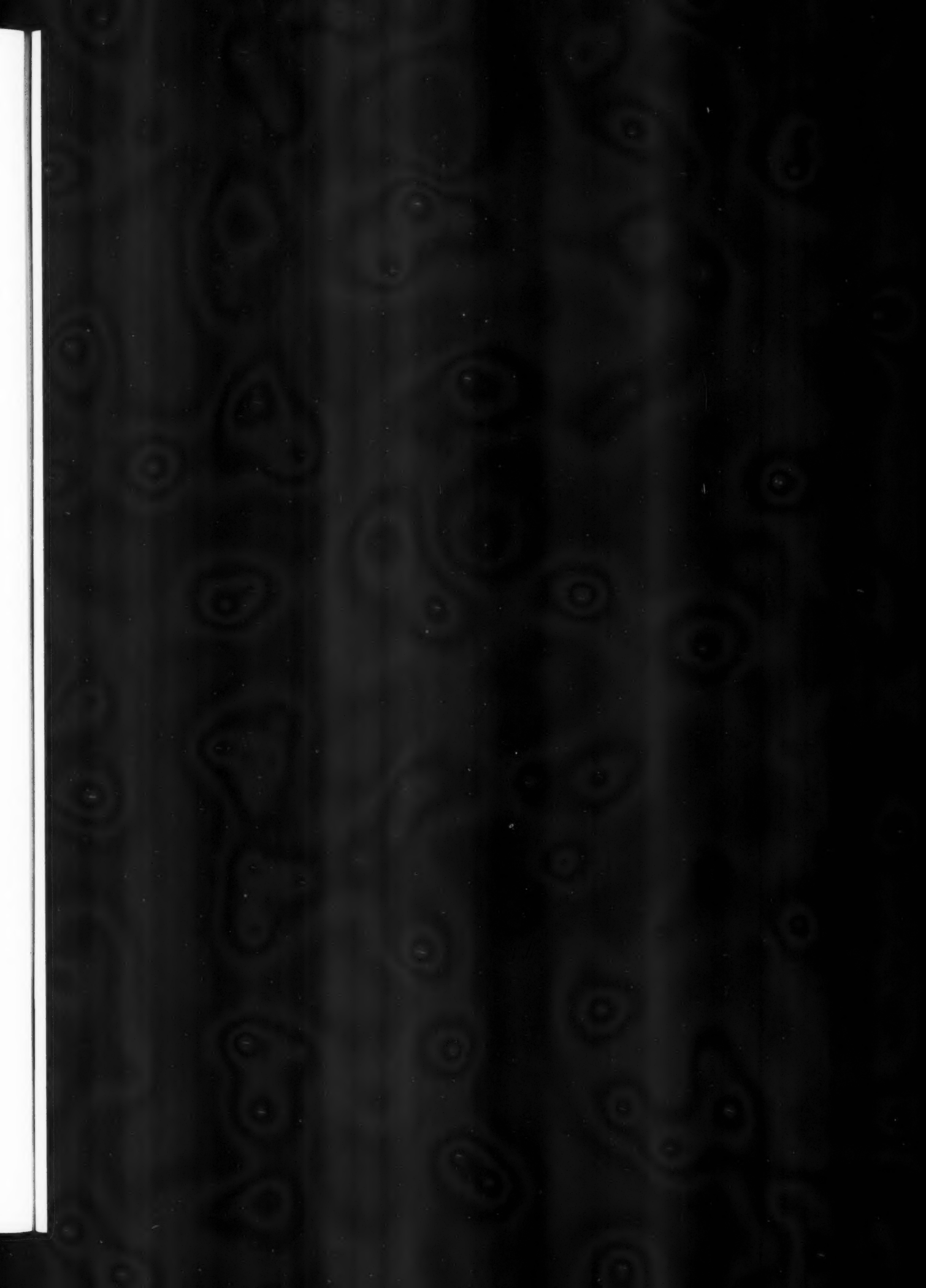

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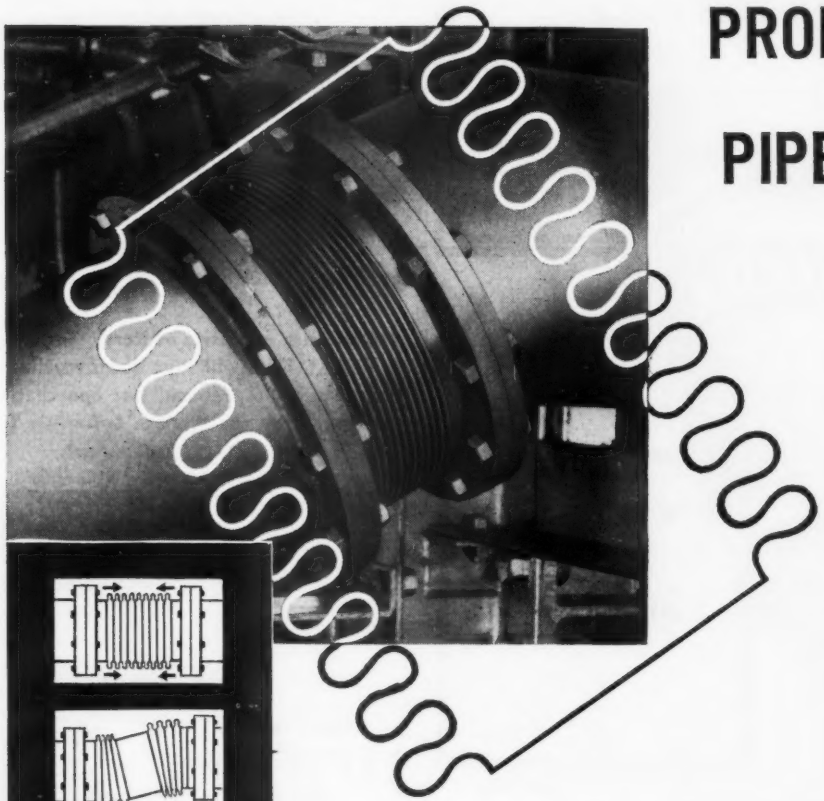

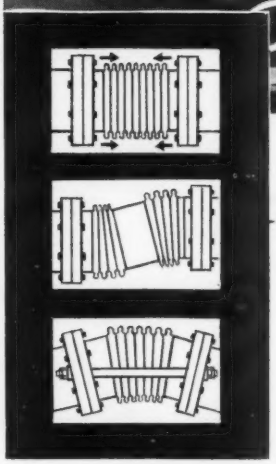

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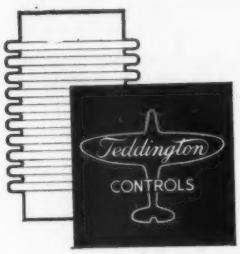

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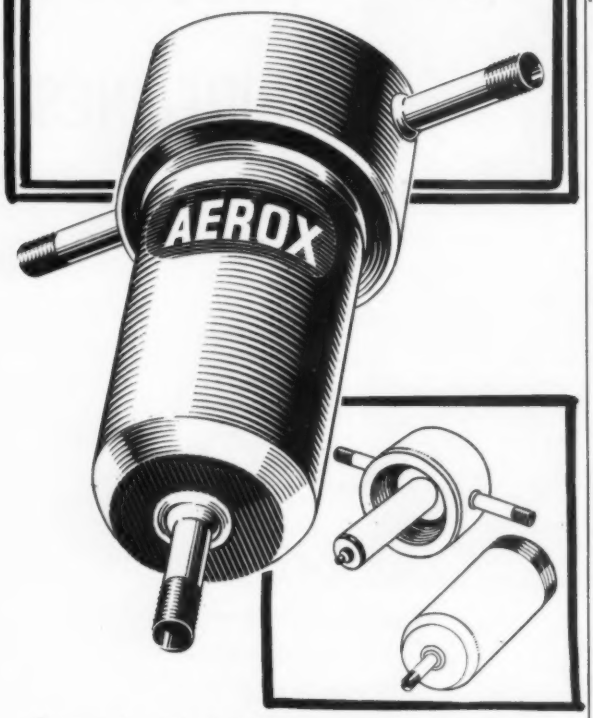
(up to 7000 p.s.i.g.)



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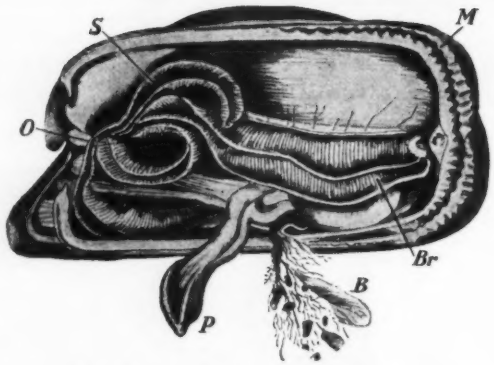

Mytilus edulis, Linné. Le lobe gauche du manteau est relevé. *O*, bouche; *S*, palpe labial externe; *Br*, branchie; *P*, pied; *B*, byssus; *M*, bord du manteau (Deshayes).

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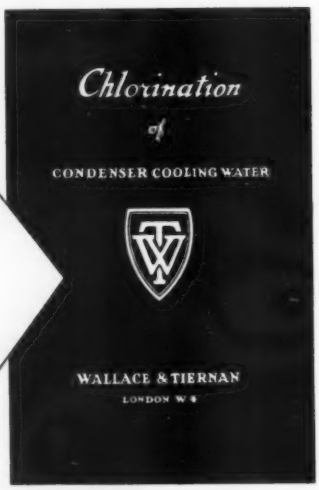

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Each fin .325″ high.

Mag x 2050

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A bundle of 250,000 such tubes could be placed inside an average sized wedding ring.

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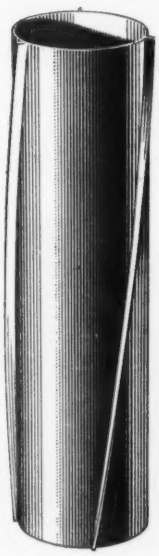

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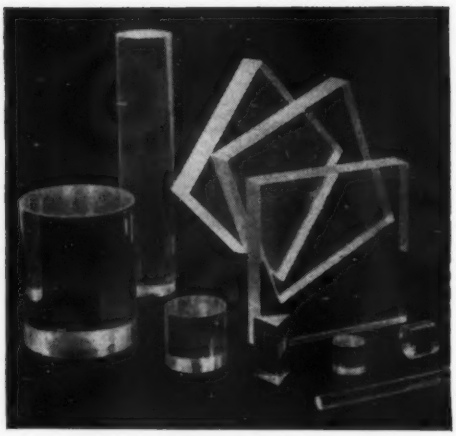

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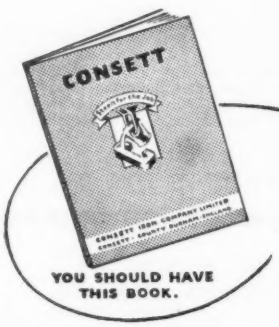

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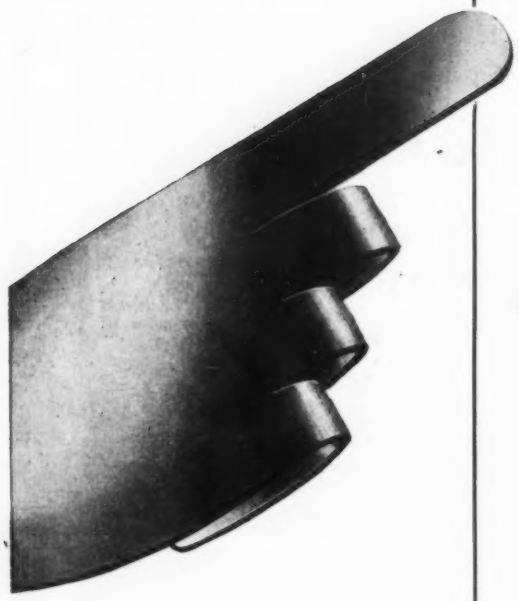

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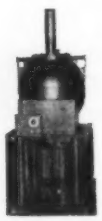

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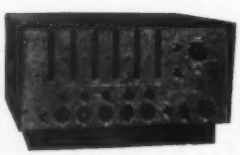

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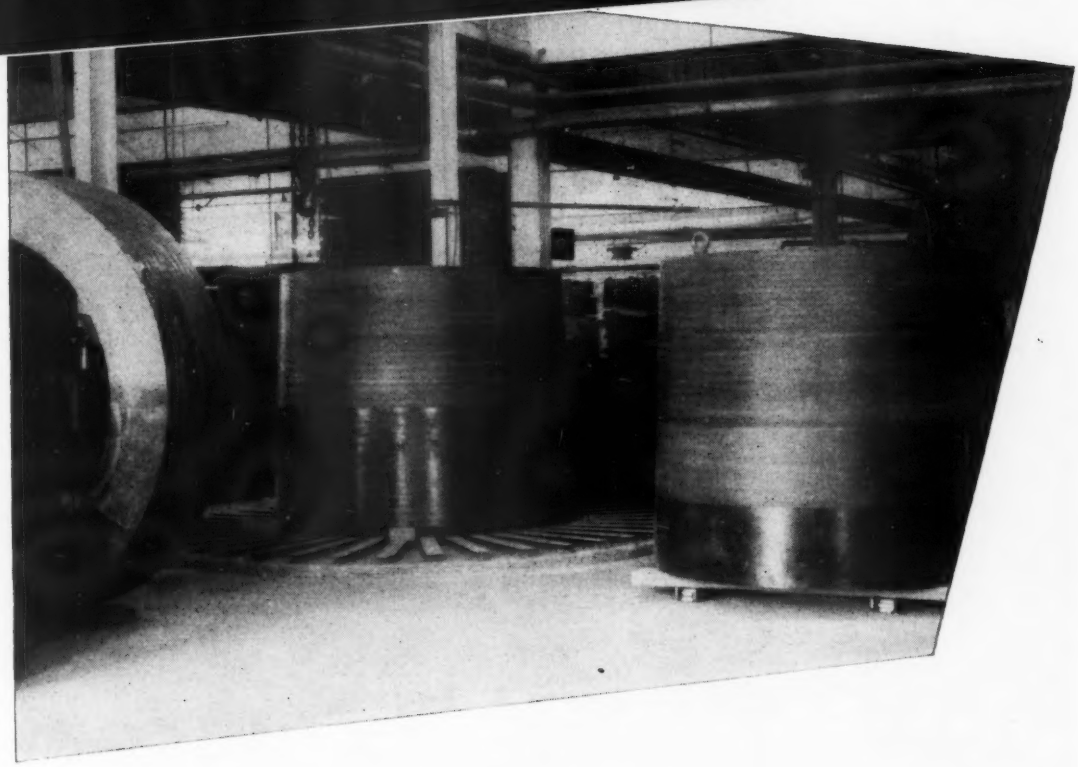

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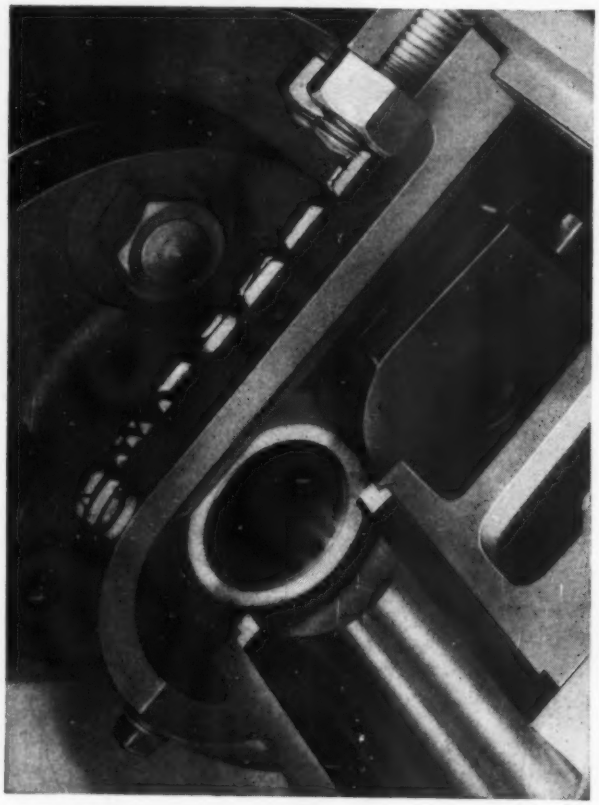

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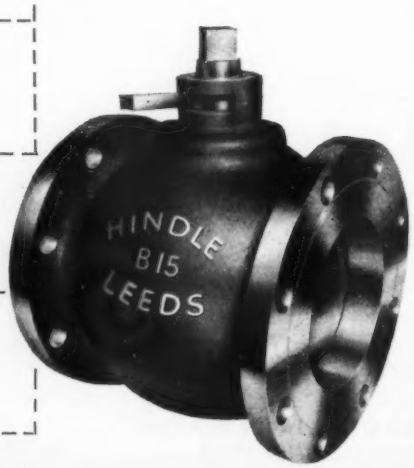

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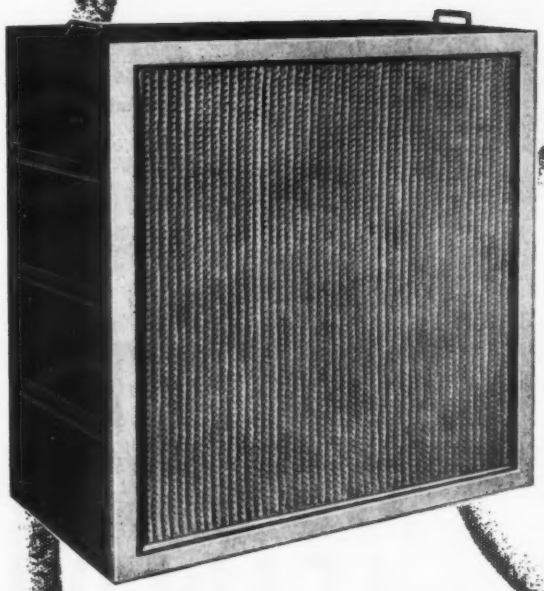

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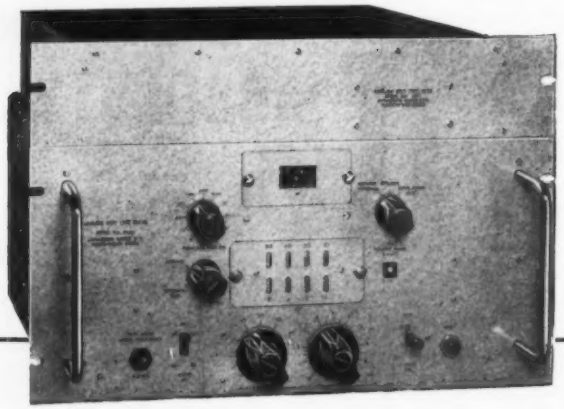

DYNATRON SCALER type 1009E

This instrument counts random or regular electrical impulses of amplitude greater than a pre-determined value between ±5 and ±50 volts. Built-in cooling unit incorporated.

SPECIFICATION

Pulse input: Positive, 0.25μs minimum duration.

Discriminator: 5V-50V.

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Paralysis Times: Switch Selection 5, 10, 20, 50, 100, 200, 500μs; 1, 2, 5, 10 milliseconds.

Speed: This is limited by mechanical register to 2,500 per second, but may be improved by the use of an extended high speed register.

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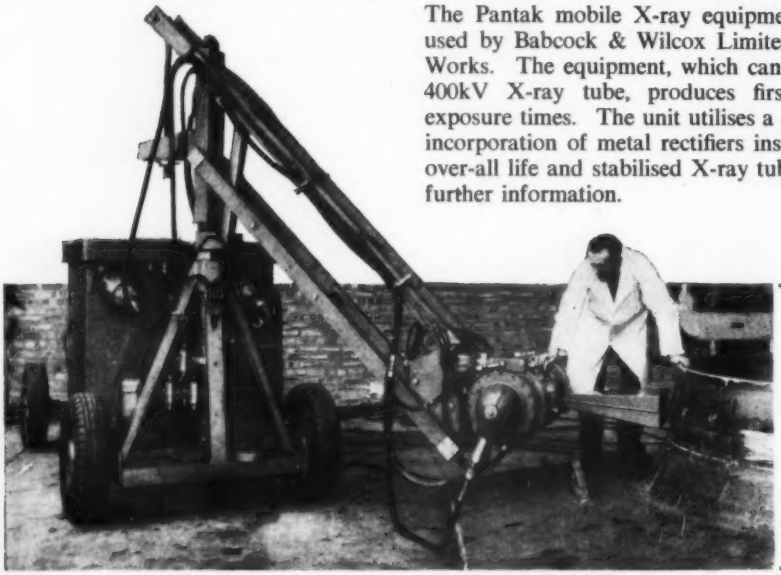
Pantak mobile X-ray equipment for non-destructive examination

The Pantak mobile X-ray equipment illustrated, is one of the five used by Babcock & Wilcox Limited at their Dalmuir and Renfrew Works. The equipment, which can be fitted with either a 300kV or 400kV X-ray tube, produces first-class radiographs using short exposure times. The unit utilises a constant potential circuit, and the incorporation of metal rectifiers instead of valves results in a longer over-all life and stabilised X-ray tube performance. Please write for further information.



MAXIMUM MANOEUVRABILITY

An outstanding feature of the Pantak X-ray equipment is its extreme manoeuvrability. The tube stand, consisting principally of parallel link arms operated by an hydraulic jack, gives a very wide field of movement. The tube stand is mounted on an easily towed truck with pneumatic-tyred wheels and Ackermann steering. The whole unit can easily be operated by one man at ground level.

PANTAK LIMITED

VALE ROAD · WINDSOR · BERKS
Telephone: WINDSOR 3225-6

HEAT EXCHANGERS

We have vast experience in the design and construction of heat exchangers in light alloy and stainless steel. We shall be glad to help you in this field too.

Delaney Gallay

THERMAL INSULATION BLANKETS

have been tested up to 1250°C

—but quite apart from their ability to withstand very high temperatures successfully, Delaney Gallay blankets have another big advantage for the nuclear field.

Completely encased in stainless steel, they require no maintenance and are not easily damaged.

Delaney Gallay Thermal Insulation Blankets can be made to fit both simple and complex shapes. The stainless steel sheathing is dimpled for maximum rigidity, and can be completely sealed against the ingress of liquids if necessary.

They are designed for easy fitting and removal, and can be supplied with apertures to accommodate controls.

If you would like further information, please contact us. We shall be happy to supply it.

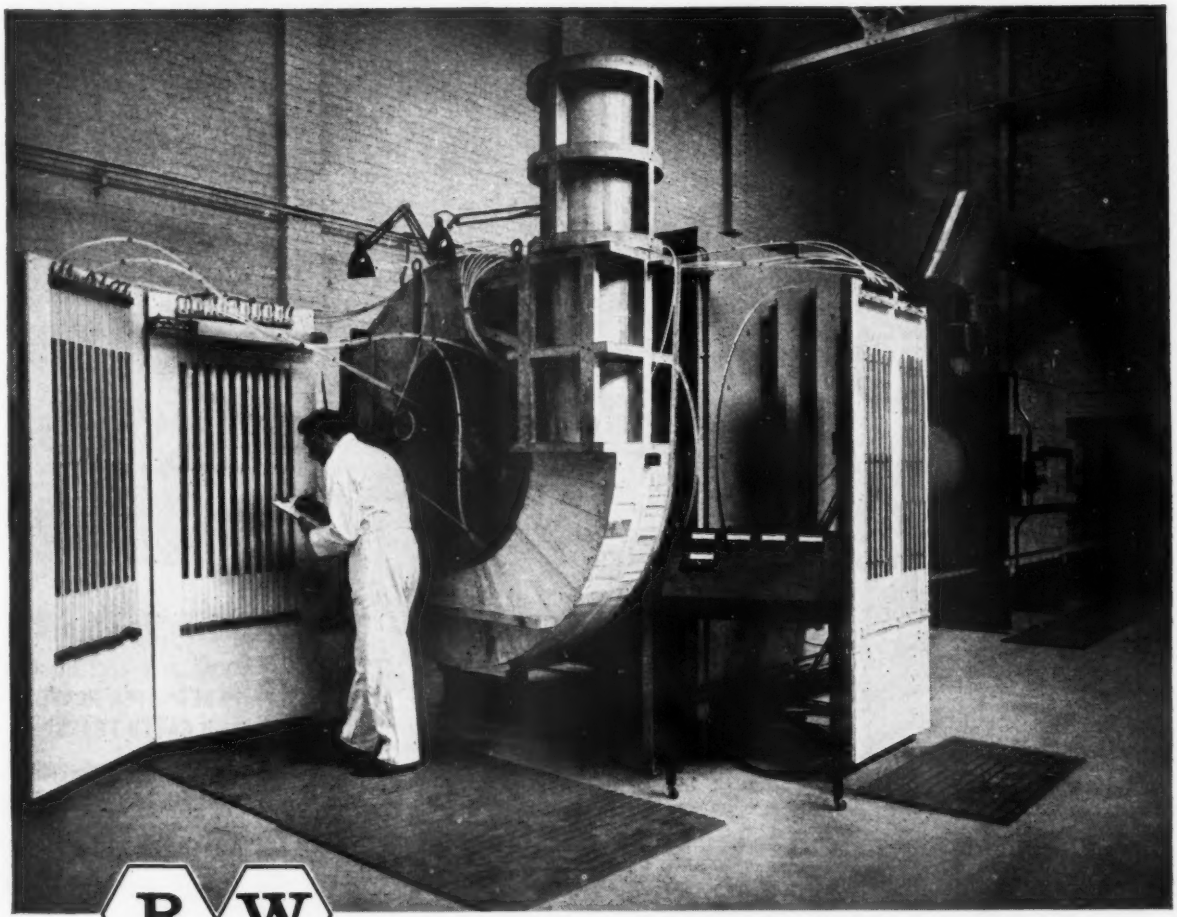
Delaney Gallay LTD *Experts in Heat Exchange & Heat Insulation for over 40 years*

Vulcan Works, Edgware Road, London, N.W.2. Tel: GLAdstone 2201

You'll get no stock answers here!

On the Development side at Richardsons Westgarth we work from principle, not precept, and use a conventional solution to a problem only when we are sure it is the economic one.

It is this outlook that has enabled us to provide new answers to many problems in mechanical engineering, from turbo-machinery to sea-water distillation plant.



R W G

In the Aerodynamics Laboratory of the Richardsons Westgarth Group, an engineer tests an air flow model of the outlet diffuser and volute assembly for a high-speed centrifugal compressor. These volutes and diffusers will be used on a number of gas turbo-compressors at present being manufactured for a well-known Oil Company.

RICHARDSONS, WESTGARTH & CO. LTD.

The Controlling Company of the Richardsons Westgarth Group, Wallsend, Northumberland and at 58 Victoria Street, London, S.W.1. 59 Mosley Street, Manchester. 75 Buchanan Street, Glasgow.

RW86A

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Telcon Metals for Nuclear Engineering

These alloys cover a wide range of permeabilities, resistivities and saturation inductions. They all have low electrical losses and are widely used in electrical and electronic equipment. Typical applications include current transformer cores, magnetic screens, pulse and audio-frequency transformers, chokes, relay parts, transductors and saturable reactors, telephone diaphragms and small motors.
Most Alloys are available in cold rolled strips drawn rod and wire, and forged sections.

HIGH PERMEABILITY MAGNETIC ALLOYS

Summary of typical properties

Magnetic Properties	Supermumetal 50	Mumetal	Radiometal	Super Radiometal	Radiometal 36	R.2799
Initial Permeability	50 000	40 000	3 500	10 000	2 000	
Maximum Permeability	200 000	100 000	30 000	100 000	10 000	70 at 0°C 48 at 20°C
Saturation Ferric Induction (gauss)	8 000	8 000	16 000	16 000	12 000	3200 at 0°C 2200 at 20°C
Remanence, Brem, from saturation (gauss)	5 000	4 700	10 000	11 000	3 500	
Coercivity, Hc. (oersteds)	0.01	0.04	0.15	0.04	0.30	
Hysteresis loss at B sat (erg/cc/cycle)	13	38	1 000	400	450	
Curie Point (C)	390	390	500-550	500-550	280	60

Your enquiries are invited

TELCON METALS LTD

Manor Royal · Crawley · Sussex

Telephone: Crawley 1560

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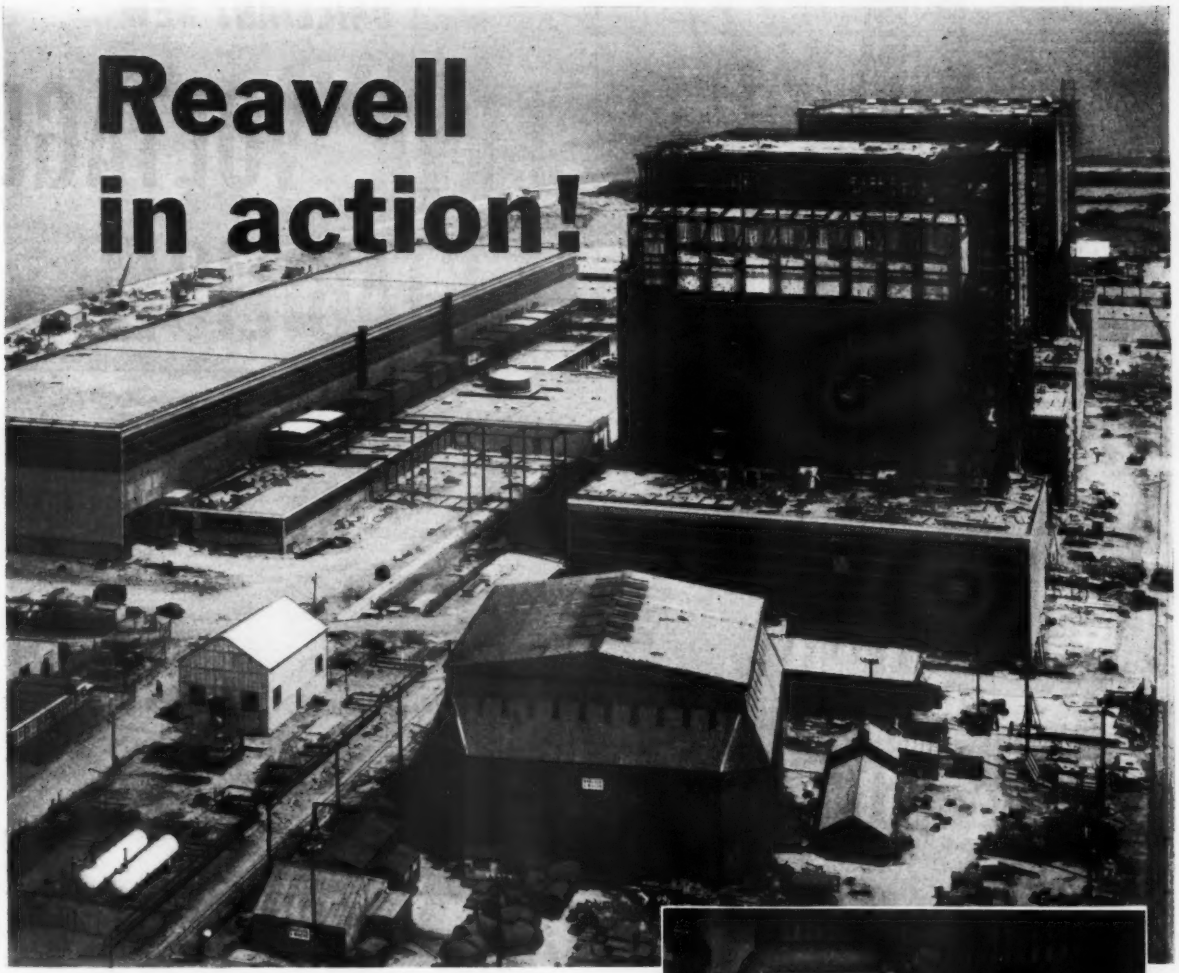
H.C.R. A rectangular hysteresis loop alloy for Magnetic amplifiers and saturable reactors. Saturation induction: 15 600 gauss Retentivity: 15 000 gauss Coercivity: 0.13 Oe Hysteresis loss—650 ergs/cm³/cycle Bmax = 15000
Strip wound spiralcores are readily available in most standard thicknesses.

MEMBER OF THE **BICC** *GROUP OF COMPANIES*

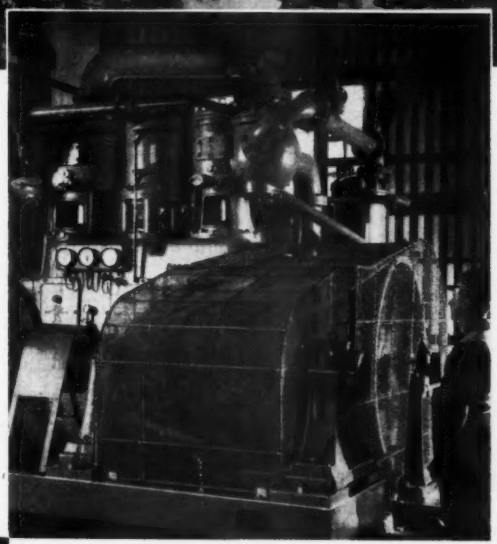
Reavell in action!



Here at Hinkley Point, where the world's first 500,000 kW. nuclear power station is almost complete, you'll find **Reavell** commissioning compressors used for pressure testing the reactor circuit. Two double acting three-crank three-stage air compressors, each delivering 1,100 cu.ft. of free air per minute when running at 325 r.p.m., are mounted, with their motors, on skid beds for easy movement.

When the Hinkley Point station is completed, these compressors (together with a third **Reavell** compressor and a booster) will be transferred to Sizewell, where the country's most powerful nuclear power station is already under construction, to carry on the good work.

In the field of nuclear power, as in so many other industries today, **Reavell** *is the first name in compression.*



Reavell

REAVELL & CO., LTD.
RANELAGH WORKS, IPSWICH, SUFFOLK.
TELEPHONE: IPSWICH 56124

MAKERS OF COMPRESSORS AND EXHAUSTERS FOR ALL INDUSTRIES

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New Design by

BUTTERS

gives even greater derrick crane efficiency

PANORAMIC VISION FOR THE OPERATOR
SAFER, FASTER CONTROL
BETTER PERFORMANCE
and various detail refinements

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1 kVA VOLTAGE STABILISER

FAST **40 volts/sec correction speed**

ACCURATE **Better than ±0·5%**

RELIABLE **Transistorised control unit — no valves or relays**

The TS-1 is something entirely new in the field of A.C. voltage stabilsation. This light and compact 1 kVA unit provides rapid, accurate and distortionless stabilisation over an input voltage range of 25%. Alternative connection gives 2 kVA output with 12½% input range.

Output is unaffected by variations in supply frequency, load current (zero to full load) or load power factor. Indoor tropical rating is standard. Cabinet model (readily adaptable for wall or chassis mounting) or rack model.

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Claude Lyons Ltd.

VALLEY WORKS · HODDESDON · HERTS
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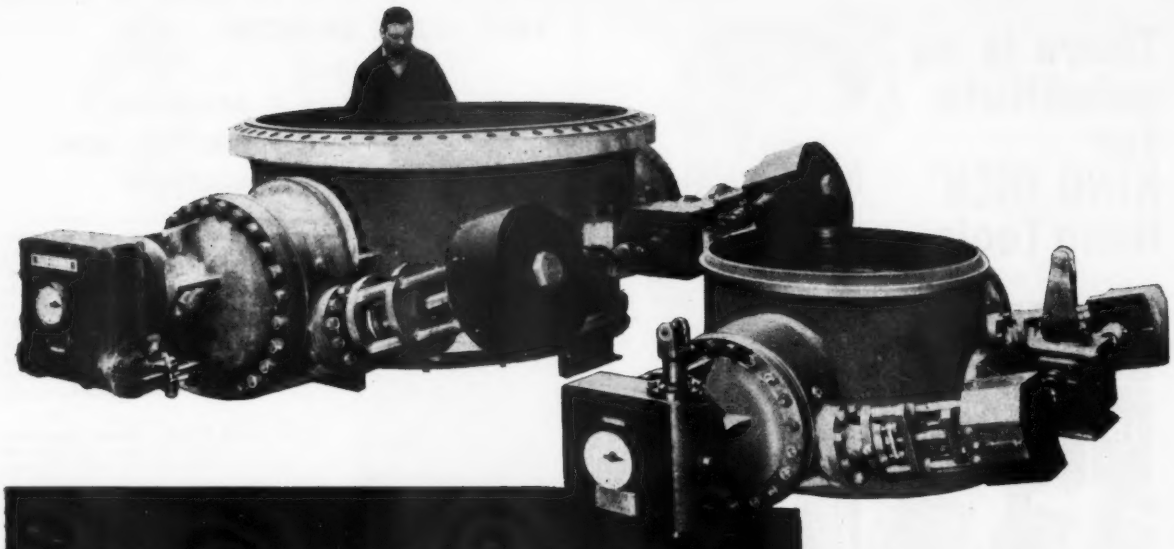
CL63/3

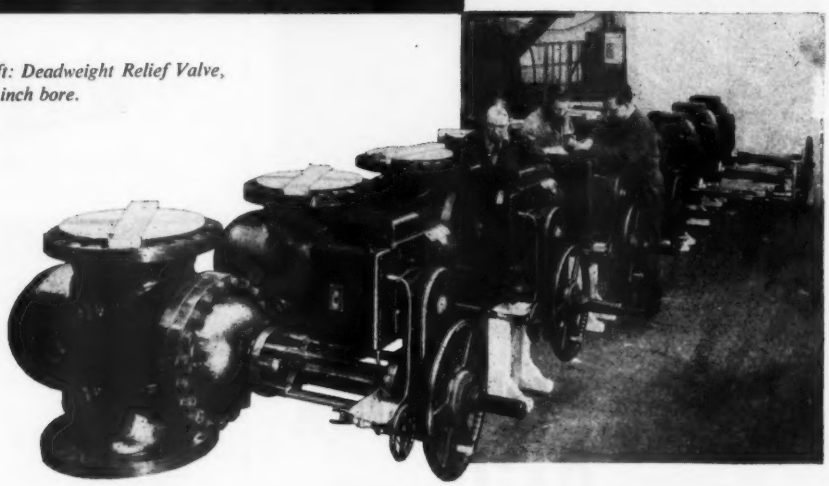


HOPKINSONS' VALVES FOR NUCLEAR POWER STATIONS

Above: "Tansphere" Valves for isolating CO_2 gas between reactor and steam generating plant. Supplied or on order for Bradwell, Hinkley Point, Latina and Trawsfynydd (Valves illustrated are 60 inch and 36 inch bore).

Below: Group of 24 inch electrically-controlled Hopkinson-Ferranti valves for a nuclear power station.

Left: Deadweight Relief Valve, 20 inch bore.



Specialised valves (some of which are illustrated) needed in nuclear power stations are naturally entrusted to Hopkinsons because of their vast experience in the manufacture of valves for exacting duties. But, additionally, Hopkinsons are supplying large numbers of their electrically controlled valves, desuperheating equipment, combined stop and isolating valves, automatic exhaust valves, steam traps and all types and sizes of stop valves.

HOPKINSONS LIMITED · HUDDERSFIELD

LONDON OFFICE: 34 NORFOLK STREET · STRAND · W.C.2

Hopkinsons' valves and fittings have been supplied or are on order for:

Calder Hall	**Hinkley Point**
Dounreay	**Latina (Italy)**
Chapelcross	**Trawsfynydd**
Berkeley	**Windscale**
Hunterston	**Dungeness**
Bradwell	**SIZEWELL**

HV121

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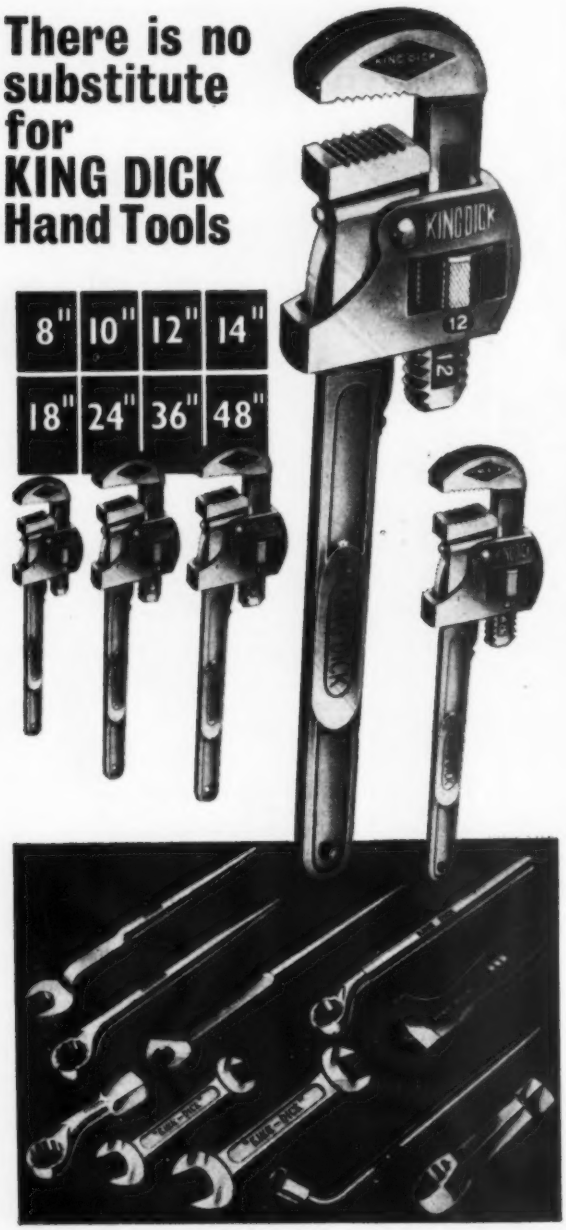

King Dick have added a 12″ model to their range of Stillson Wrenches. Together with the renowned King Dick quality of design and finish, it provides the finest and fullest range available. All parts interchangeable.

KING DICK Stillson Wrenches

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accurate particle size analysis

Accurate and consistent results are the features required of a test sieve shaker for the sieve analysis of the particle size range of material. Simply vibrating or shaking test sieves by hand is not good enough for the standard of accuracy required these days. Vibration alone tends to aggregate rather than to segregate particles and shaking test sieves by hand is not only tedious but inevitably produces inaccurate results.

The **Inclyno Test Sieve Shaker** incorporates a double movement that jolts and spreads the test material ensuring perfect segregation of the various particle sizes and presenting the maximum number of apertures for undersize particles to fall through each sieve. Three models available for all sizes of standard test sieves and supplied complete with motor and inbuilt automatic time switch covering test periods up to 60 minutes.

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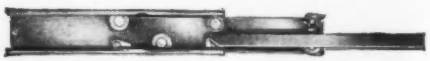
Extension Drawer Slides, Door Runners and Castors.
Ask for List No. 275



3-piece Slides 12¼″ to 28¼″ and 2-piece Slides 10″ to 25¼″
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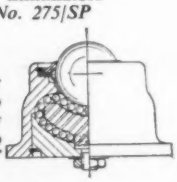

Omni-Track Conveyor Ball Transfer Units up to 20 tons capacity each. Load balls ½″ to 4″ dia. *List No. 275/OT*

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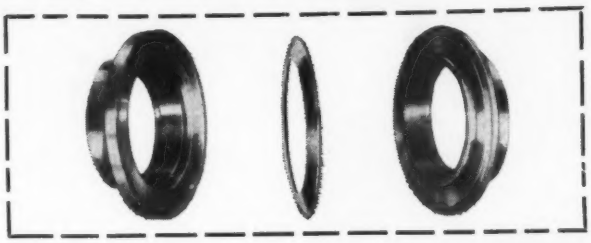
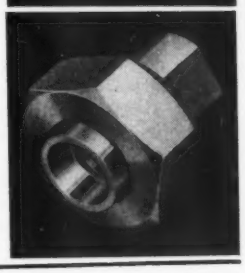


KING *Conoseal* HEAVY DUTY PIPE COUPLINGS

ZERO LEAKAGE

in conditions of extreme temperature and pressure

Robust, dependable, corrosion resistant Conoseal Couplings provide the perfect joint on heat transfer systems, pressure and vacuum lines and cryogenic systems. Consisting of two cone flanges, a frustro conical gasket and a V-Band Clamp; the Conoseal Coupling is easily installed and assembled.



Above right
Heavy Duty Conoseal Coupling with 3 segment clamp

Right
Conoseal Union Fittings for joining all types of small diameter tubing.

KING AIRCRAFT CORPORATION

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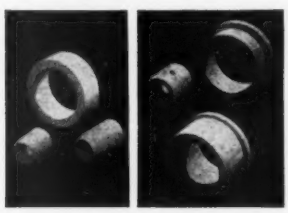

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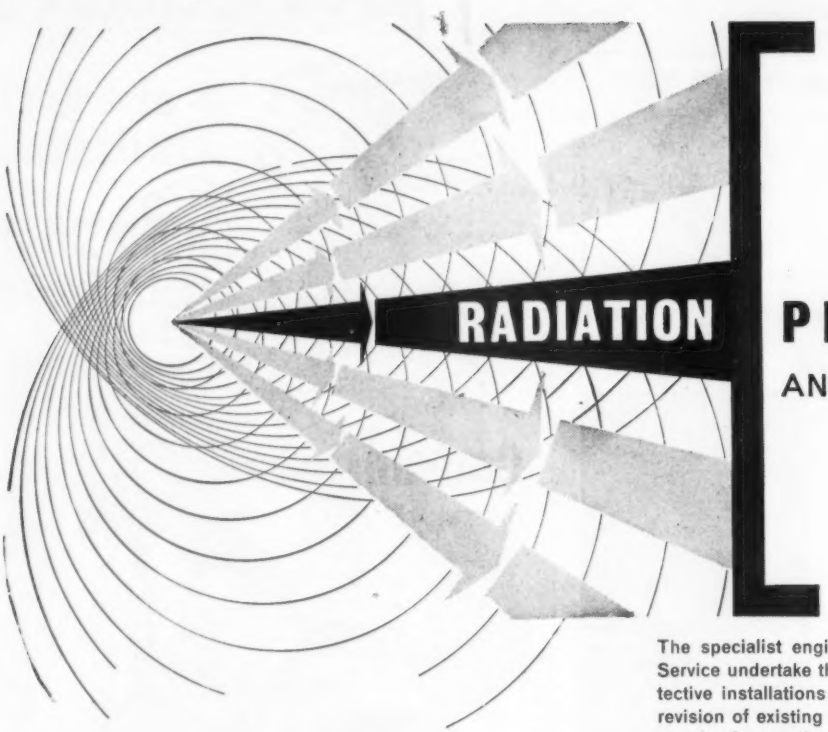

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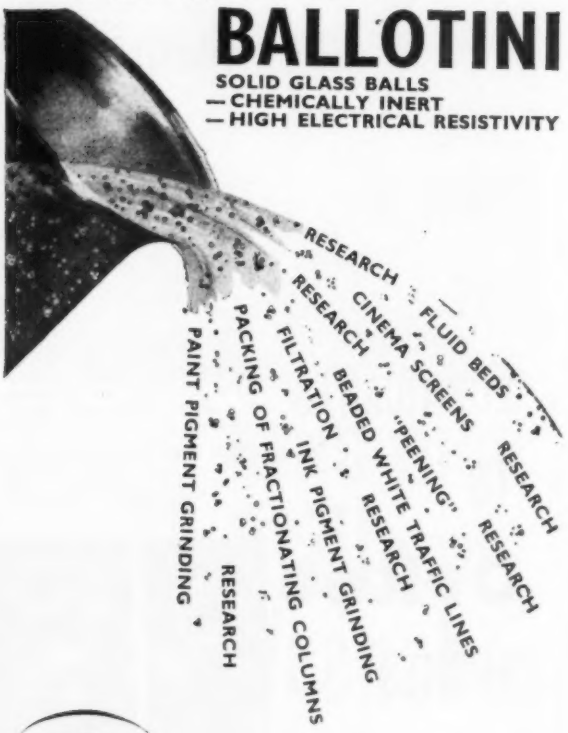

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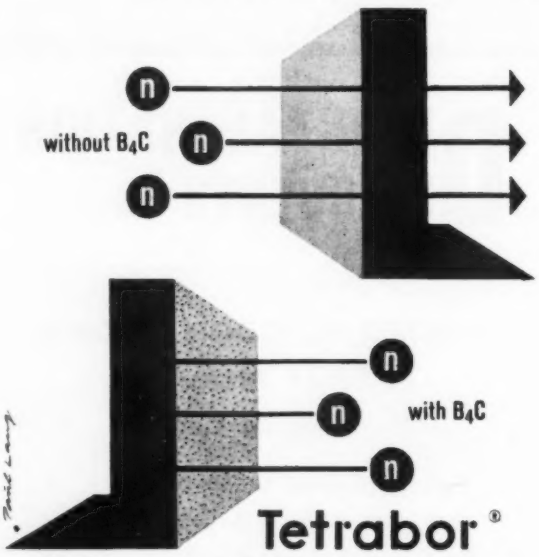

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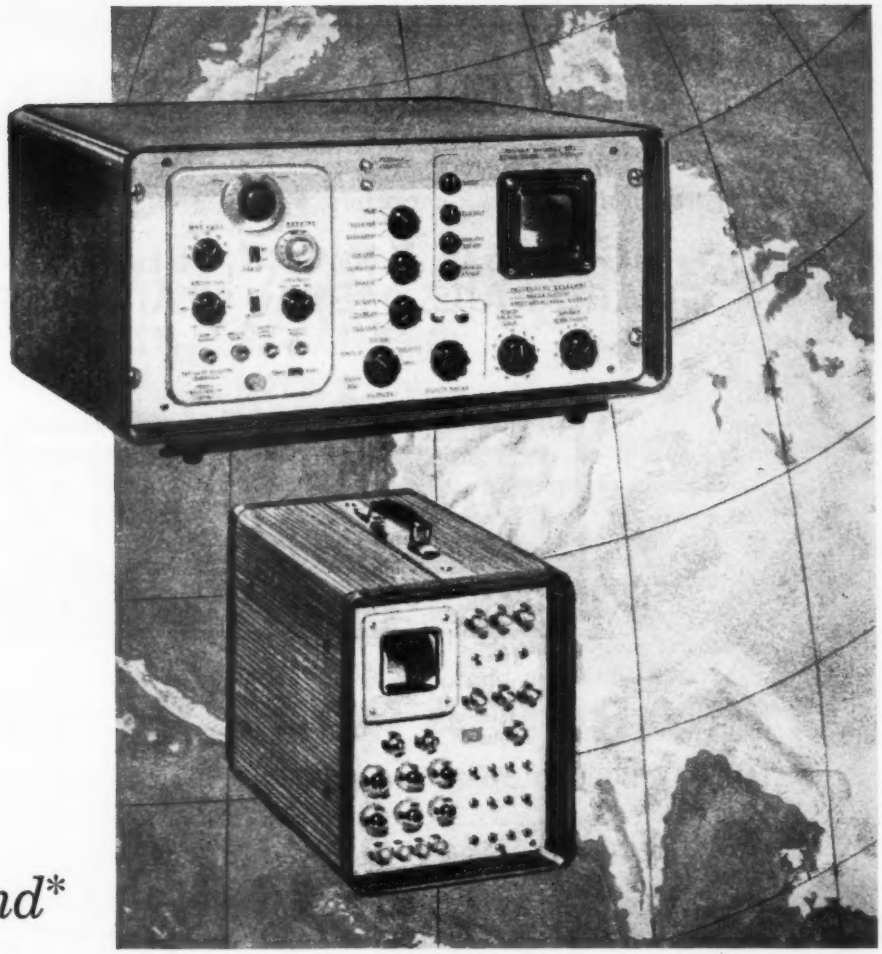
*What's good for nuclides in New Haven is good for those in New Zealand**



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The TMC CN-110 256 channel analyzer offers 7 interchangeable plug-in logics, including pulse height, time of flight, pulsed neutron, multiscaler, mass spectrometer, and coincidence pair. This widely used and thoroughly proven analyzer (over 100 units have been delivered) employs all-transistorized circuitry. Analog, binary, octal and decimal readout may be used. Data can be recorded on strip chart or X-Y recorders, printed paper tape, punched paper tape, or punched cards.

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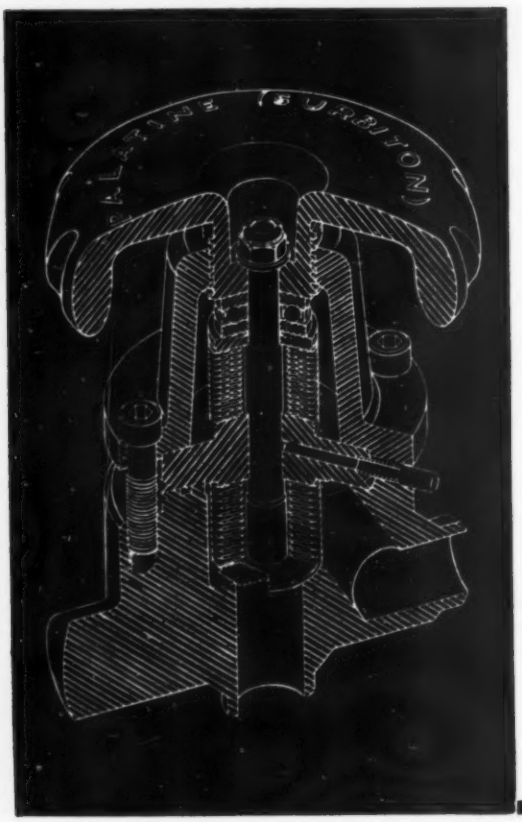

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PRECISION HELICAL POTENTIOMETERS
4 sizes

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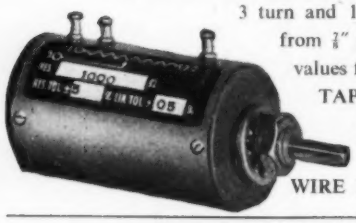
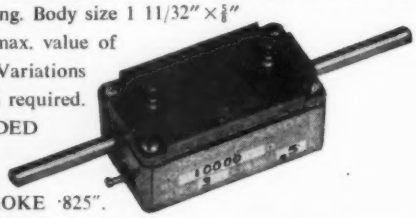


PRECISION RECTILINEAR POTENTIOMETERS

Series PL05 is a single gang unit with tapped hole mount, sleeve bearing. Body size 1 11/32" × $\frac{5}{8}$" × $\frac{1}{4}$" with max. value of 10,000Ω Variations available as required. TAP WELDED CONNECTIONS. MAX. STROKE ·825".



PRECISION SERVO POTENTIOMETERS
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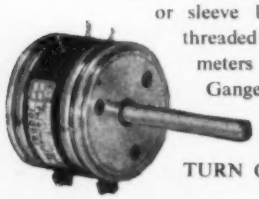
Series PR are single turn potentiometers, ball or sleeve bearing with servo, bushing or threaded hole mounting of $\frac{1}{2}$" to 3" diameters with values from 1Ω to 175KΩ. Ganged form and sin/cos types available. ALL TAP WELDED CONNECTIONS. TAPPINGS OFF ONE TURN OF WIRE IN ANY POSITION.



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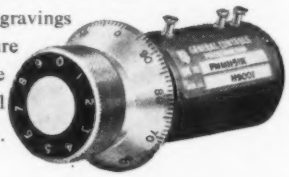

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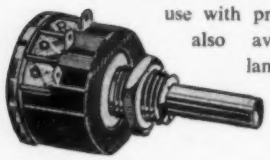

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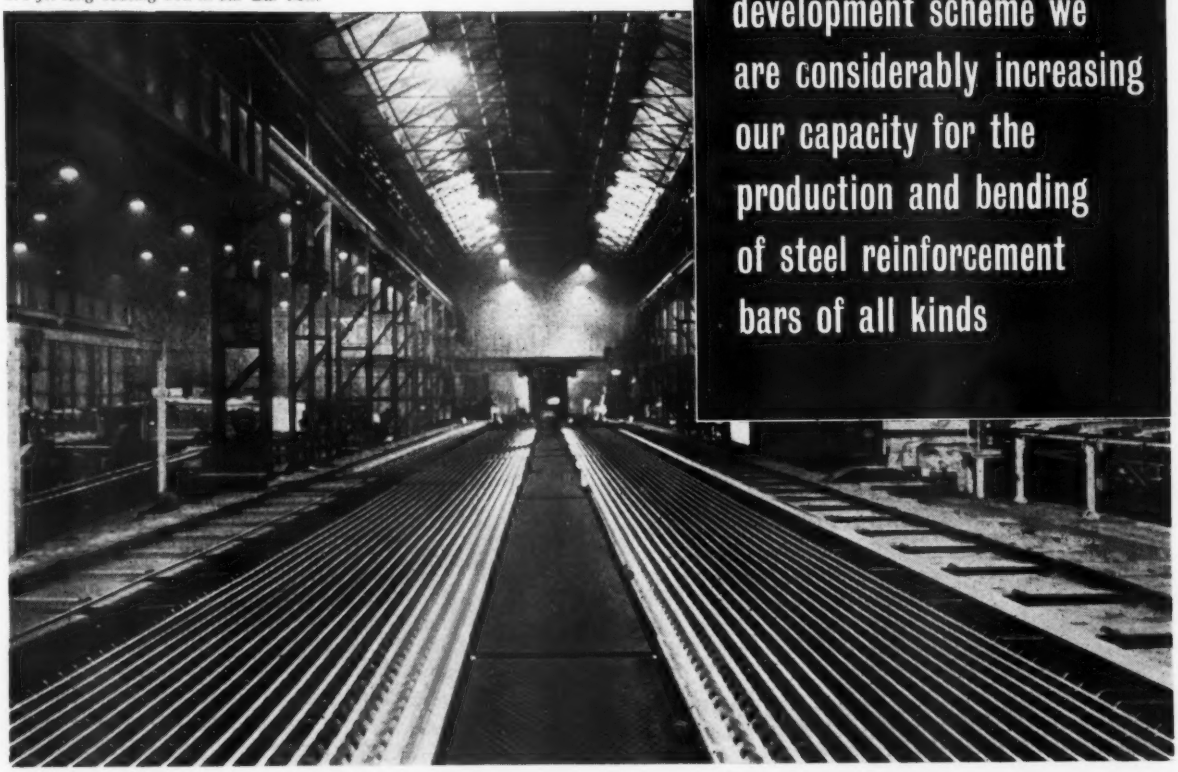

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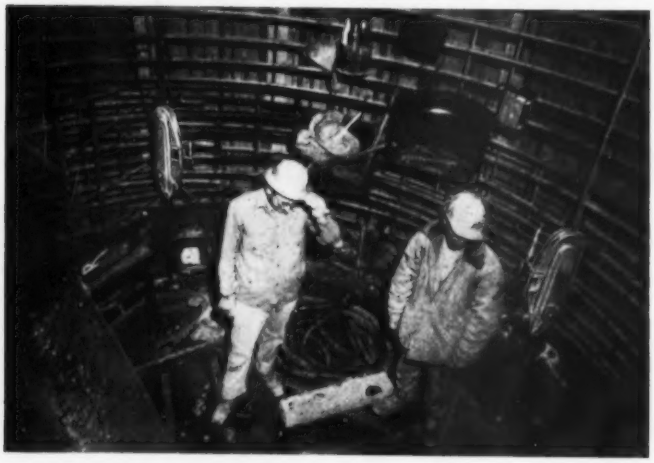

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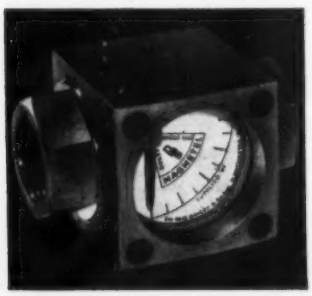

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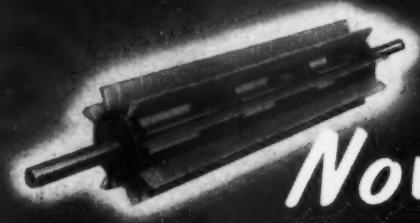

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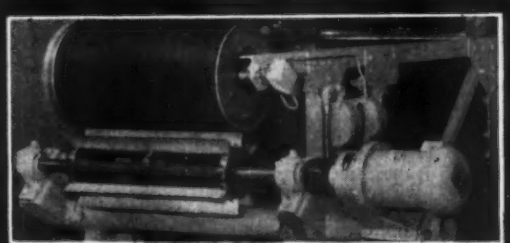

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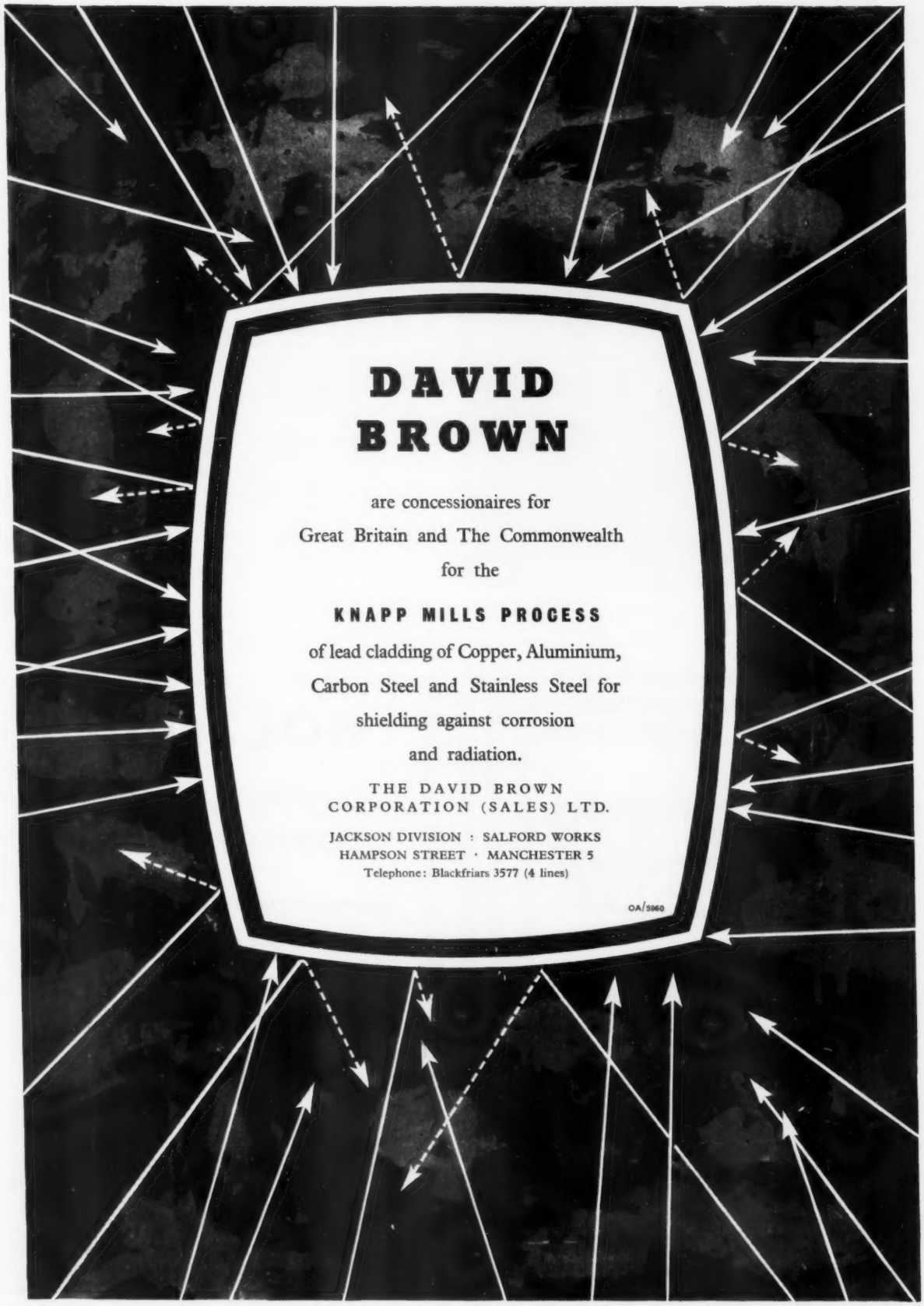
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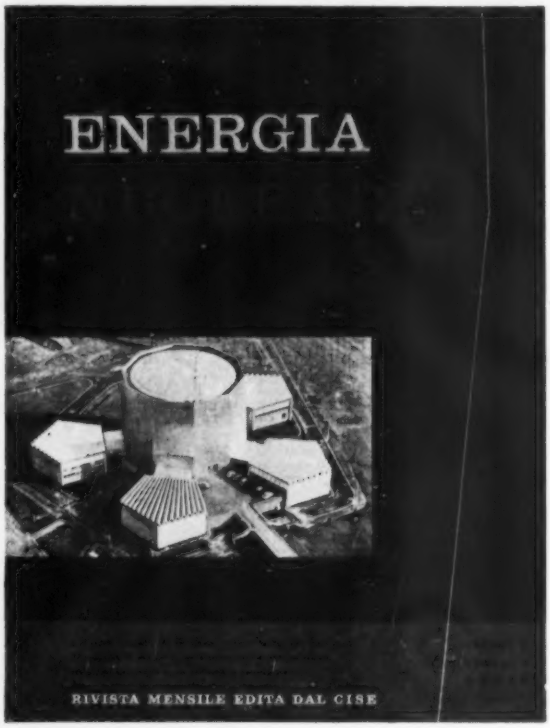

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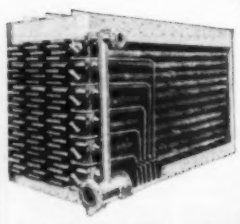

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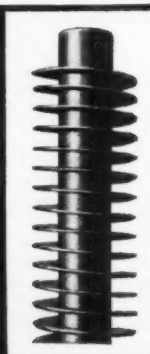

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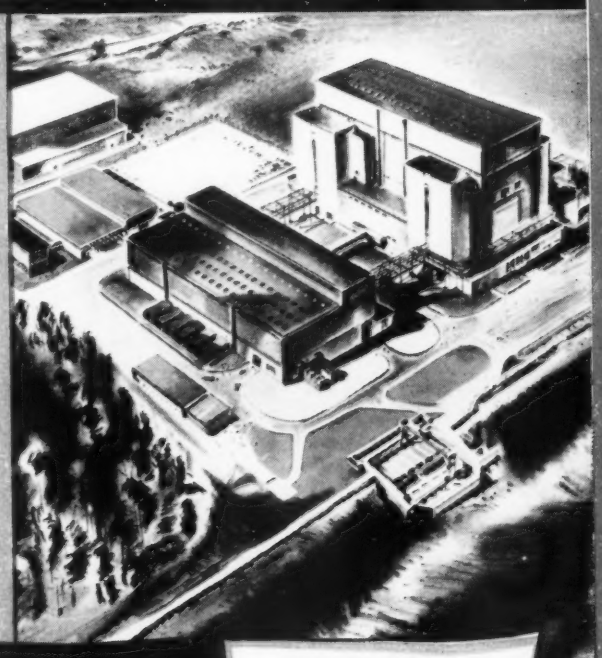

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